Commercial in confidence

Virginia offshore wind port readiness evaluation

Report 1: An evaluation of 10 Virginia ports

A report to the Virginia Department of Mines, Minerals and Energy

April 2015

Document history

Revision	Purpose and description	Originated	Checked	Authorized	Date
1	For client release	AER	CJN	BAV	29 April 2015
2	Updated tables 6.1 - 6.17	AER	CJN	BAV	17 June 2015

BVG Associates

BVG Associates is a technical consultancy with expertise in wind and marine energy technologies. The team probably has the best independent knowledge of the supply chain and market for wind turbines in the UK. BVG Associates has over 150 person years experience in the wind industry, many of these being “hands on” with wind turbine manufacturers, leading RD&D, purchasing and production departments. BVG Associates has consistently delivered to customers in many areas of the wind energy sector.

Apex Companies

Apex delivers planning, engineering, environmental, and consulting services to clients across the United States and abroad. Apex has been at the forefront of port and site selection for the first purpose-build offshore wind support facility in the United Sates located in New Bedford, Massachusetts.

Offshore Design Engineering

ODE is an international engineering contractor to the offshore oil, gas and renewable energy markets providing comprehensive range of consultancy, engineering, project and construction management and O&M services. ODE have been involved in the development of some 400MW of offshore wind encompassing a majority of current UK project, plus providing considerable ongoing engineering and management support to North American and German markets.

Timmons group

Timmons group provides civil engineering, environmental, geotechnical, geospatial/GIS technology, landscape architecture and surveying services to a diverse client base. Timmons Group is headquartered in Richmond, Virginia.

Global Wind Network

GLWN is an international supply chain advisory group with a mission to increase the domestic content of North America’s wind energy installations, onshore and offshore. GLWN’s manufacturing engineering and wind supply chain expertise has been significantly leveraged these past two years with key projects specific to offshore wind component production for the U.S. Department of Energy, the National Renewable Energy Labs, Lawrence-Berkley Labs, the Massachusetts Clean Energy Center, and the New Bedford (MA) Economic Development Council.

Clarendon Hill Consulting

CHC provides inter-disciplinary consulting services in environmental and urban planning, port infrastructure and vessel analysis for the offshore wind industry and Geographical Information Systems (GIS), as well as general project management.

The views expressed in this report are those of BVG Associates and its partners. The content of this report does not necessarily reflect the views of Virginia DMME.

Contents

List of figures

List of tables

Executive Summary

BVG Associates led a team commissioned by The Virginia Department of Mines, Minerals and Energy to evaluate 10 Virginia ports for their readiness to accommodate seven different offshore wind manufacturing and construction activities:

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing
- Foundation manufacturing
- Submarine cable manufacturing, and
- Construction staging.

The team also evaluated five Virginia commercial shipyards for their readiness to manufacture offshore substations.

This report is one of three in this study. The other two other reports present port utilization scenarios for offshore wind manufacturing and staging and high-impact investment opportunities.

Drawing on intelligence from established offshore wind industry suppliers, we developed a set of optimal requirements for each offshore wind activity. The requirements included the waterside infrastructure, the onshore infrastructure for the activities themselves and the access requirements for vessels associated with offshore wind activities. They excluded the buildings or equipment that would be used for each activity.

Virginia has a thriving port and shipbuilding sector and the ports were chosen by Virginia DMME as having significant available areas of land adjacent to quaysides. Other ports are likely to be suitable for offshore wind activities if they become available.

Through dialog with property owners, site visits and desktop research, we built up a database of characteristics for the 10 ports. We then assessed the readiness of each port for each offshore wind activity in turn.

For some activities in some ports, necessary upgrades are either unfeasible or likely to be uneconomic. In these cases, we did no further evaluation.

Although offshore wind activity is more demanding on port infrastructure than many other commercial port activities,
.

Virginia's ports offer a high level of readiness. We concluded that five ports have a realistic potential to be used for one or more offshore wind activities. These were:

- Portsmouth Marine Terminal
- Newport News Marine Terminal
- Peck Marine Terminal
- Virginia Renaissance Center, and
- BASF Portsmouth.

Each of the ports requires upgrades to meet offshore wind requirements. This report provides details of the required upgrades specific to each activity at each port. These upgrades are summarized in Table 0.1.

Portsmouth and Newport News Marine Terminals

PMT and NNMT have the highest level of port readiness. They each have sufficient space to accommodate multiple, co-located offshore wind activities, making them candidates for a future offshore wind manufacturing and deployment hub. The necessary upgrades to meet offshore wind requirements would cost up to $10 million at each port.

Peck Marine Terminal

Peck has the space and vessel access to accommodate many of the offshore wind manufacturing activities. Overhead navigational clearance precludes using Peck for foundation manufacturing and construction staging. Necessary upgrades at Peck would cost up to $14 million.

Virginia Renaissance Center

VRC has a high level of readiness but faces navigation constraints. Blade manufacturing and submarine cable manufacturing could be located at VRC and necessary upgrades would cost up to $5 million.

BASF Portsmouth

BASF Portsmouth represents an opportunity to develop new port infrastructure and would require a larger investment of $8 million to $45 million.

Commercial Shipyards

We concluded that five Virginia shipyards are capable of manufacturing conventional offshore substations without further infrastructure investment. Two of these facilities had dry docks suitable for manufacturing self-installing substations.

Table 0.1 Summary of implementation analysis.

The grey cells indicate an activity not suitable at the port. $$ = implementation cost; = Time line; = construction jobs

	Portsmouth Marine Terminal	Newport News Marine Terminal	Peck Marine Terminal	Virginia Renaissance Center	BASF Portsmouth
Blade manufacturing	**$$:** $3.0 million-$10.8 million : 23 months : 15.2 FTE-years	**$$:** $2.9 million-$7.9 million : 15 months : 10.6 FTE-years	**$$:** $2.4 million-$8.7million : 7 months : 2.5 FTE-years	**$$:** $1 million-$5 million : 2 months : 1.6 FTE-years	**$$:** $13.3 million-$37.2 million : 3.5 years : 14.5 FTE-years
Generator manufacturing	**$$:** $3.0 million-$10.8 million : 23 months : 15.2 FTE-years	**$$:** $2.9 million-$7.9 million : 15 months : 10.6 FTE-years	**$$:** $1.3 million-$7.2 million : 6 months : 0.7 FTE-years		**$$:** $9.9 million-$32 million : 3 years : 12.8 FTE-years
Nacelle assembly	**$$:** $4.7 million-$16.5 million : 2.5 years : 25.2 FTE-years	**$$:** $4.5 million-$12.1 million : 2.5 years : 16.7 FTE-years	**$$:** $2.7 million to $13.8 million : 12 months : 4.2 FTE-years		**$$:** $13.9 million to $37.9 million : 3.5 years : 14.8 FTE-years
Tower manufacturing	**$$:** $5.9 million-$18.9 million : 2.5 years : 27.4 FTE-years	**$$:** $5.7 million-$14.5 million : 20 months : 18.9 FTE-years	**$$:** $5.1 million to $6.8 million : 4 months : 1.4 FTE-years		**$$:** $13.9 million to $44.7 million : 4 years : 16.3 FTE-years
Foundation manufacturing	**$$:** $5.4 million to $12.5 million : 25 months : 19.2 FTE-years	**$$:** $5.3 million to $13.8 million : 19 months : 17.6 FTE-years			**$$:** $9.3 million to $31.8 million : 2.5 years : 12.4 FTE-years
Submarine cable manufacturing	No upgrades required	No upgrades required	**$$:** $900,000 to $1.3 million : 1 month : 0.5 FTE-years	**$$:** $900,000 to $1.3 million : 1 month : 0.5 FTE-years	**$$:** $12.5 million to $38.9 million : 2.5 years : 14.7 FTE-years
Substation manufacturing	*Substation manufacturing readiness was evaluated at commercial shipyards. No upgrades are required. See Section 5.11*				
Construction staging	**$$:** $7.3 million to $17.3 million : 2.5 years : 27.3 FTE-years	**$$:** $7.1 million to $14.4 million : 2.5 years : 21.6 FTE-years			**$$:** $13.5 million to $38.9 million : 3.5 years : 14.7 FTE-years

1. Introduction

Virginia Department of Mines, Minerals and Energy (DMME) commissioned BVG Associates (BVGA) and its partners to evaluate the readiness of Virginia's ports to support offshore wind farm manufacturing and construction.

This is the first of three reports produced as outputs from the analysis. Table 1.1 lists these reports.

Table 1.1 Reports produced as part of the Virginia offshore wind port readiness evaluation study.

Number	Title
Report 1	An evaluation of 10 ports
Report 2	Port utilization scenarios for manufacturing and wind farm staging
Report 3	High-impact investment opportunities

This report presents an evaluation of 10 Virginia ports that have available or under-used waterfront infrastructure. These are shown in Figure 1.1 and are:

- Portsmouth Marine Terminal
- Newport News Marine Terminal
- Cape Charles Harbor
- Norfolk Southern Lamberts Point
- Peck Marine Terminal
- BASF James City
- Gravel Neck
- Virginia Renaissance Center (ex-Ford Plant)
- Steel Street in Chesapeake (ex-Orca Yachts), and
- BASF Portsmouth.

We evaluated the ports for the following offshore wind activities:

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing
- Foundation manufacturing and staging
- Submarine cable manufacturing, and
- Construction staging.

We also evaluated Virginia's commercial shipyards for readiness to manufacture offshore substations.

Section 2 of this report provides an overview of Virginia's port infrastructure to give context to the findings.

Section 3 describes the methodologies used in this evaluation, including:

- How we determined the port requirements and actual port characteristics
- How we evaluated the ports against the requirements, and
- How we estimated the implementation costs for port upgrades.

Section 4 presents a detailed set of port requirements for each of the eight offshore wind activities.

Section 5 describes an initial evaluation of the 10 ports for each of the seven offshore wind activities, and concludes which ports appear most suitable for upgrading for each activity. Section 5 also presents the shipyard readiness evaluation for offshore substations.

Finally, Section 6 presents the investments needed to upgrade existing port infrastructure to meet the requirements for each activity. It also includes an evaluation of the associated construction jobs (full-time equivalents; FTEs) and time lines associated with each upgrade.

Report 2 considers different scenarios for accommodating offshore wind activities in Virginia. Report 3 draws this analysis together to identify the highest impact investments that could be made.

In establishing the requirement for port infrastructure, we assumed a market demand for 100 offshore wind turbines per year. The potential offshore wind market near Virginia is about 2,000 to 5,000 turbines over 10 years starting in 2020. We based this projection on the full build-out of the Virginia, North Carolina, Maryland, Delaware, and New Jersey Wind Energy Areas as currently defined by the US Bureau of Ocean Energy Management (BOEM). These wind energy areas are all within approximately 250 nautical miles of Cape Henry, Virginia.

We based our evaluation on detailed consultation with experienced industry suppliers. We are grateful to the following companies that contributed:

- Alstom Power
- Blade Dynamics
- Bladt
- Gamesa
- Keystone Engineering
- LM Wind Power
- MHI Vestas Offshore Wind
- Oceaneering
- Prysmian, and
- Senvion.

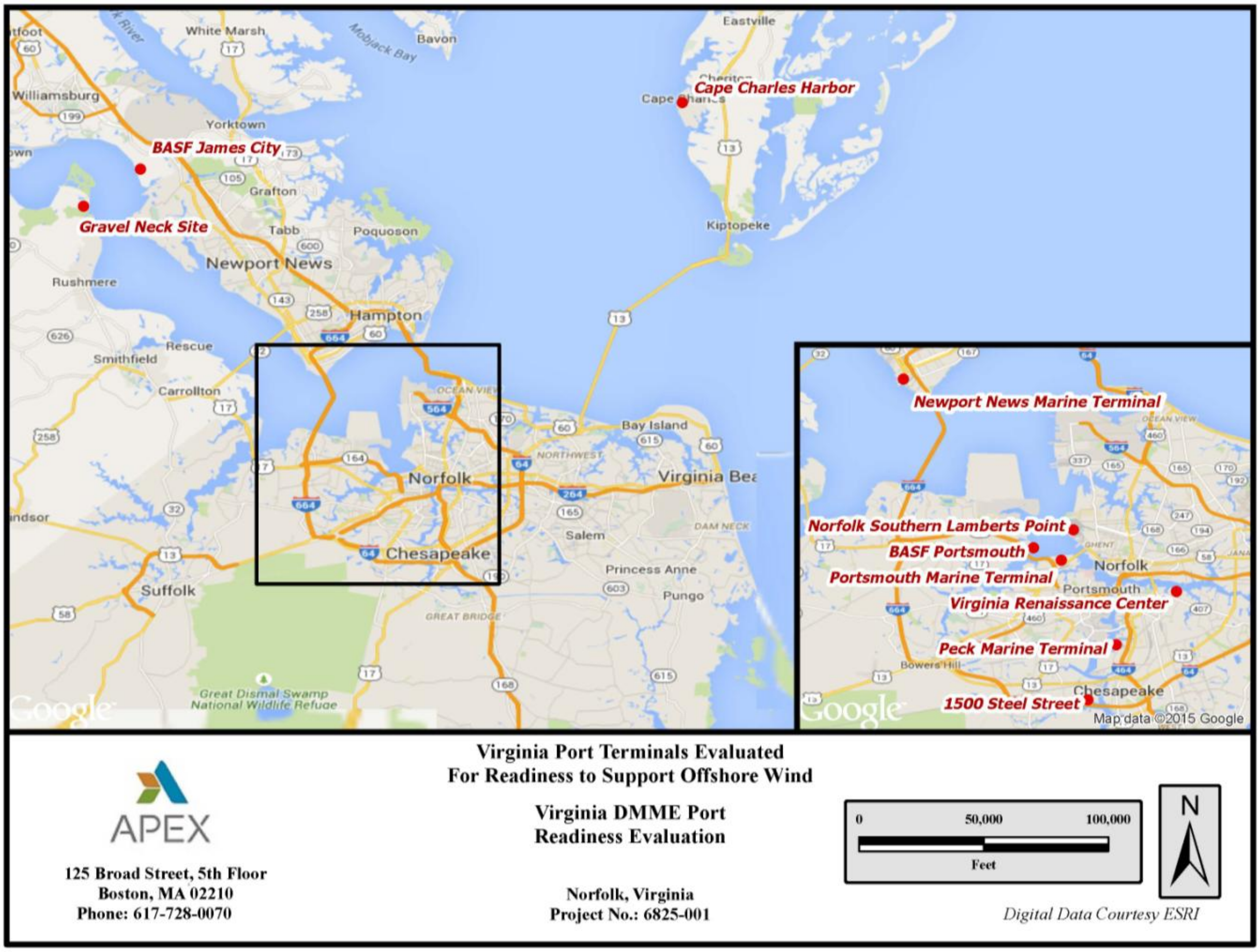

Figure 1.1 Map showing the ports considered in the evaluation.

2. Ports industry in Virginia

2.1. Current and recent uses

The Commonwealth of Virginia has thriving, world-class military and commercial ports. Commercial ports handle containers, bulk commodities, roll-on/roll-off cargo, and inter-modal transshipment (ship-to-train). Shipbuilding, primarily military, is also flourishing in Virginia.

Many of Virginia's ports have naturally deep water, unobstructed access to the open sea, or both. Waterfront facilities of every shape, size, and development level can be found in the Hampton Roads area and further inland along the James River and Elizabeth River.

Some ports are decommissioned industrial sites used for such purposes as textile manufacturing, automotive manufacturing, oil storage and yacht building. Others are undeveloped green field sites. There are also highly developed container terminals and ship-to-rail facilities.

2.2. Ownership of Virginia ports

Virginia ports are under both public and private ownership. The Virginia Port Authority, "a component of the Commonwealth of Virginia", controls three publically owned major marine terminals and leases these to private operators. These public facilities offer an opportunity for major public-private partnerships that could lead to offshore wind "super-ports" in which wind turbines are loaded directly onto specialist offshore installation vessels. Realizing these opportunities will require investment in the ports and may require changes to the current port leasing business model.

Virginia also has many privately owned ports and maritime facilities such as shipyards. Some are thriving, some are under-used, and others are vacant or completely undeveloped. Some of these privately owned sites are being actively marketed for lease or sale and therefore may offer a good route for establishing offshore wind manufacturing and construction support facilities in Virginia.

Table 2.1 summarizes the ownership and current use for the 10 ports evaluated in this study.

Table 2.1 Ownership and current use of the evaluated ports.

Port	Ownership	Current Use
Portsmouth Marine Terminal	Public	Container shipping
Newport News Marine Terminal	Public	Container shipping
Cape Charles Harbor	Private	Vacant
Norfolk Southern Lamberts Point	Private	Transshipment (vessel-to-rail)
Peck Marine Terminal	Private	Manufacturing (partial)
BASF James City	Private	Vacant
Gravel Neck	Private	Vacant
Virginia Renaissance Center	Private	Vacant (former Ford truck plant)
Steel St Chesapeake	Private	Construction support
BASF Portsmouth	Private	Vacant

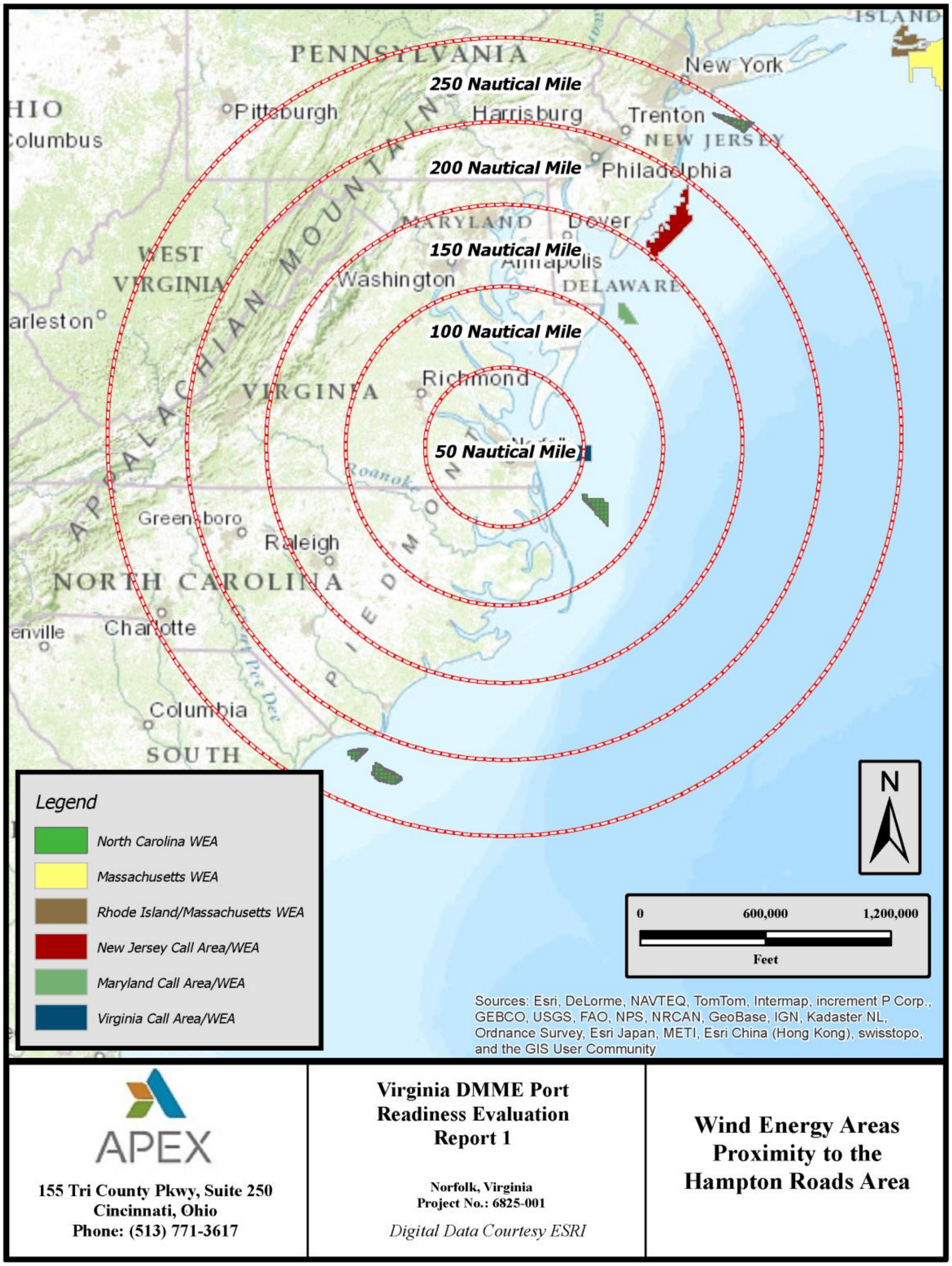

Figure 2.1 Wind Energy Areas and Call Areas within 250 nautical miles of the Hampton Roads area.

3. Methodology

We evaluated 10 ports for this study. Virginia DMME chose nine of these based on earlier analysis. We identified three additional ports that were available, had waterfront access and greater than 80,000m^2 of space. These were BASF Portsmouth, Chesapeake Deepwater Terminal, and CSX Piers 14 and 15.

In discussion with Virginia DMME, we added BASF Portsmouth to this evaluation since it represented a unique opportunity to create new port infrastructure. Chesapeake Deepwater and CSX Piers 14 and 15 were not included since they were similar to other ports under consideration.

We undertook the evaluation in four main stages:

1. Industry requirement assessment, in which we:
   a. Developed port requirements for each of the eight activities based on our collective knowledge and experience
   b. Gathered detailed input from each of our industry partners
2. Port parameter assessment, in which we:
   a. Undertook desk-based research
   b. Gathered outstanding information
   c. Undertook site visits
3. Evaluation, in which we:
   a. Screened ports for potential use
   b. Made interim conclusions, and
4. Implementation analysis, in which we:
   a. Estimated implementation costs and time lines for necessary port upgrades and improvements.

3.1. Industry requirement assessment

We based the port requirements on manufacturing and constructing 100 units per year. Turbines installed in US east coast waters over the next 10 years are likely to have a rated capacity of between 5MW and 8MW and have a rotor diameter of between 130m and 180m (blade length between about 63m and 83m). There are significant cost benefits of larger turbines and we therefore assumed that demand will be at the upper end of this range when defining requirements.

For the foundations, we assumed that space frame structures such as jackets will be made as these are likely to be the technology choice for Mid-Atlantic wind farms. Monopile manufacturing does not have more demanding infrastructure requirements than jacket manufacturing.

We assumed that the average array link will be 1.7km (10 times the rotor diameter).

Export cable requirements are based on an interconnection distance of 55km.

For quayside and water access requirements, we assumed that the vessels used to support manufacturing and construction in Virginia are similar to those that will be used in Europe from 2016. We present an overview of these vessel types in Section 4.1.

We chose port parameters to align with Department of Energy (DOE) Port Readiness Database, so the data we gathered in this project would be consistent.

Focus areas were:

- Waterside infrastructure
- Water depth
- Road and rail access
- Utility connections, and
- General site condition.

For substations, we assumed that orders would be placed with commercial shipyards (or offshore fabrication yards) and that new, bespoke manufacturing facilities will not be developed. We therefore evaluated the readiness of Virginia's existing commercial shipbuilding sites to build two substations per year.

For the eight activities, we undertook a two-stage process to capture the port infrastructure and waterway requirements needed by industry tenants:

1. Aggregated the considerable existing knowledge of the project team, then
2. Filled knowledge gaps and validated data through targeted questionnaires and discussions with industry.

Existing offshore wind manufacturing and construction facilities have rarely been designed exclusively for the sector. Also, some compromises are inevitable in selecting a site. Significant variations in the specifications of existing facilities are therefore likely and it was necessary to consolidate the data we gathered and choose a reasonable value or range of values for each parameter to cover most likely medium-term needs.

3.2. Port parameter assessment

We researched the parameters for each of the 10 Virginia ports, in three stages:

1. Desktop research
2. Interviews with port owners, and
3. Site visits.

Desktop research focused on publicly available reports, GIS data, National Oceanic and Atmospheric Administration (NOAA) navigational charts, marketing materials and information provided from port operators and users.

We approached port owners initially through a letter from Virginia DMME presenting the project team and requesting interviews. Through this engagement and follow-up correspondence, we gathered more background data, gained a better understand the current uses, and identified the key contacts for setting up site visits.

We made site visits in February 2015. Each visit lasted two to five hours and focused on acquiring better documentation of the condition of the existing infrastructure, reviewing current operations, talking with on-site personnel, and gaining an on-the ground perspective.

We were unable to gather detailed data on subsurface conditions, particularly ground strength and quayside conditions, which are important factors in offshore wind development ports. Instead, we made assumptions about ground strength based on current uses and anecdotal information. These assumptions are noted in Section 6.

We were unable to gain access to the Gravel Neck Site and the Virginia Renaissance Center within the required time line of this evaluation. Instead, we made our assessment by visiting adjacent properties. We also corresponded with the key personnel for each of these properties who were able to provide useful information. We were also unable to visit the Norfolk Southern Lambert's Point facility due to lack of availability of on-site personnel, but did we correspond with its general manager.

3.3. Port evaluation

We convened a team workshop to conduct a review of the suitability of each port for each offshore wind activity. We graded each combination using the criteria in Table 3.1

Table 3.1 Grading of port suitability for each offshore wind activity.

Grade	Definition	Examples of constraint or work needed
Green	Site is suitable for the activity with minimal upgrade	• Resurfacing
Yellow	Site is suitable for the activity with significant upgrade	• Maintenance dredging • Targeted improvement dredging • Strengthening of existing waterside infrastructure • Defined-scope environmental remediation
Orange	Site is suitable for the activity with major upgrade	• New waterside infrastructure • Extensive improvement dredging • Full green-field development
Red	Site is unsuitable for the activity	• Air draft limitation • Insufficient space • Water depth (dredging disallowed or impractical)

We presented this evaluation to Virginia DMME in a face-to-face meeting and agreed that we would not undertake the implementation analysis for site-activity combinations rated orange or red.

3.4. Implementation analysis

For each site rated green or yellow for an offshore wind activity, we calculated the costs, time lines and construction jobs for completing necessary infrastructure upgrades. We did not address the cost of building and outfitting the manufacturing facilities, as these costs are dependent on each manufacturer's preference.

We calculated the cost of upgrading a port to meet a wind industry manufacturer's needs without being over-specified, that is, the upgraded ports are "optimal".

The upgrades included the following construction activities:

- Repair of existing infrastructure to current specification
- Ground strength improvements
- Pier and quayside improvements, and
- Dredging.

Costs

For each activity at each site, we compared the port requirements to the actual conditions to develop a work scope for infrastructure upgrades.

Due to uncertainty in ground bearing strength, we considered two strategies:

- Spread point loads across a larger area using cross-laminated timbers, and
- Repair or replace pier supports and decking.

We also considered the use of plastic materials, for example those made by Cultec, for areas requiring infill, such as drainage ponds.

For each upgrade, we divided the work scope items into components and quantities for cost estimating.

Using standard cost-estimating resources, including estimating manuals and recent public bid documents, we developed a common set of unit costs for the various infrastructure upgrades (such as the cost per cubic meter for dredging).

We calculated the component upgrade costs by multiplying the specific quantities by unit costs. This is an efficient, consistent and commonly used means of evaluating a large number of upgrade scenarios.

Time lines

The team developed a common set of productivity rates for each type of upgrade (such as cubic meters of dredged soil per day). We based these productivity rates on estimating manuals and recent, relevant construction projects. We calculated the construction implementation time by multiplying the productivity rates with the specific quantities for each upgrade.

We developed engineering and permitting time lines using the project team's experience of similar infrastructure projects and local dialogue.

The total upgrade time is a combination of the engineering, permitting and construction implementation time.

Construction jobs

We identified a common set of daily productivity rates for each infrastructure upgrade. Each of these rates is achieved with a certain labor crew. Using the construction time lines and the labor crews required, we calculated the labor requirements for each infrastructure upgrade, and in turn for the complete port upgrade work scope. A construction job is defined as an FTE job for one year (an FTE-year).

4. Port requirements

This section presents the port readiness requirements for each of the seven activities considered, namely:

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing
- Foundation manufacturing and staging
- Submarine cable manufacturing, and
- Construction staging.

This section also presents shipbuilding readiness requirements for offshore substation manufacturing.

The vessels needing to access a given facility dictate the waterside infrastructure requirements of the port. We have considered the following vessel types:

- Jack-up vessel
- General cargo vessel
- Tug and barge
- Cable lay vessel, and
- Offshore heavy-lift derrick.

We describe these vessel types in more detail in Section 4.1.

Port readiness in the context of each of the eight activities means that the site offers the following:

- Adequate space and acceptable layout
- Suitable access for incoming materials and outgoing finished goods
- Suitable waterside infrastructure
- Environmental remediation has been undertaken or is close to completion
- Site generally cleared and ready for construction of facilities
- Suitable commuter access for workers, and
- Necessary utility connections (water, sewer, electricity and gas) in place.

Port readiness does not include site build-out such as:

- Buildings
- Machinery and cranes
- Security systems
- Paving and parking lots, and

We were unable to establish whether the sea bed alongside the quay wall suitable for jack-up operations. This is particularly important for construction staging and this should be borne in mind in considering the evaluation's conclusions.

For land parcel size, we present a range of figures for each activity and discuss to what extent tenants may be willing to compromise.

High level port requirements are summarized in Table 4.1. Sections 4.2 to 4.9 provide the basis for these requirements.

Water depth requirements are stated as mean lower low water (MLLW).

This is a primarily a quantitative analysis but commercial considerations are significant. We have not sought to establish the commercial requirements in quantitative terms but qualitatively discus these commercial considerations in our evaluation of each port.

Table 4.1 High-level port requirements for each activity.

Activity	Vessels used	Land parcel size	Waterside infrastructure	Road and rail access
Blade manufacturing	General cargo vessel Tug and barge as compromise	150,000 to 250,000m^2 (37 to 62 acres)	Quay length: 200m Bearing capacity: 2t/m^2	Need access to major highways Rail connection highly desirable
Generator manufacturing	General cargo vessel	60,000 to 75,000m^2 (15 to 19 acres)	Quay length: 200m Bearing capacity: 5t/m^2	Need access to major highways Rail connection highly desirable
Nacelle assembly	General cargo vessel	70,000 to 100,000m^2 (15 to 25 acres)	Quay length: 300m Bearing capacity: 10t/m^2	Need access to major highways Rail connection highly desirable
Tower manufacturing	General cargo vessel Tug and barge as compromise	120,000 to 200,000m^2 (30 to 50 acres)	Quay length: 300m Bearing capacity: 5t/m^2	Need access to major highways Rail connection highly desirable
Foundation manufacturing and staging	Tug and barge Jack-up vessel Offshore heavy-lift derrick	120,000 to 200,000m^2 (30 to 50 acres)	Quay length: 125m Bearing capacity: 5t/m^2	Need access to major highways Rail connection highly desirable
Submarine cable manufacturing	Cable lay vessel; Tug and barge as compromise	80,000 to 90,000m^2 (20 to 22 acres)	Quay length: 125m Bearing capacity: 2t/m^2	Need access to major highways Rail connection highly desirable
Substation manufacturing	*Substations will be built in commercial shipyards and have a different set of requirements. See Table 4.13*			
Construction staging	Jack-up vessel	150,000 to 200,000m^2 (40 to 50 acres)	Quay length: 200m Bearing capacity: 10t/m^2	Need access to major highways Rail connection highly desirable

4.1. Vessels used in offshore wind port activities

Vessels impose significant requirements on offshore wind ports. This section describes the requirements for the main vessels likely to be used.

Jack-up vessel

Jack-up vessels are used for turbine installation and some foundation installation and they typically collect components from the construction staging or foundation load-out port. The latest generations of these are self-propelled jack-up vessels with deck space 2,000 to 4,500m^2 and a crane capacity 800 to 1,500t. Maximum operational depths range from 30m to 75m. Over recent years these vessels have been purpose built for the offshore wind industry. Examples include Swire Blue Ocean's *Pacific Osprey*, GeoSea's *Innovation* and *MPI Discovery*. Offshore heavy-lift derricks are also used for foundation installation.

Table 4.2 Principal particulars of a jack up vessel.

Principal particulars	
Length	50m to 170m
Beam	20m to 50m
Draft	5m to 10m
Air draft	varies with leg length

Figure 4.1 Jack-up vessel Swire Blue Ocean *Pacific Osprey*.

General cargo vessel

General cargo vessels transport project cargo over long, open-ocean distances. Most offshore wind cargo can be carried on the main deck but sensitive cargo such as electrical equipment and nacelles needs to be carried in a cargo hold. Most general cargo vessels can self-load and unload using onboard cranes. These vessels are used extensively by the offshore wind industry to transport wind turbine nacelles, tower sections, and blades. Examples include the *BBC Amber* and Jutha Maritime's M/*V Aggersborg*.

Table 4.3 Principal particulars of a general cargo vessel.

Principal particulars	
Length	70m to 160m
Beam	20m to 30m
Draft	5m to 10m
Air draft	20m to 30m

Figure 4.2 General cargo vessel *BBC Amber*.

Tug and barge

Barges are widely used in the offshore wind industry for moving large components such as foundations, blades, cables and towers. There are two types: self-propelled and those that are “dumb” and require tugs. Barges are well suited to coastal trade activities moving large items between ports. The air draft required is determined by the cargo rather than the height of the vessel itself. There are a large number of these vessels operating globally.

Table 4.4 Principal particulars of an ocean service barge

Principal particulars	
Length	60 to 110m
Beam	20 to 30m
Draft	2.5 to 6m
Air draft	Cargo dependent

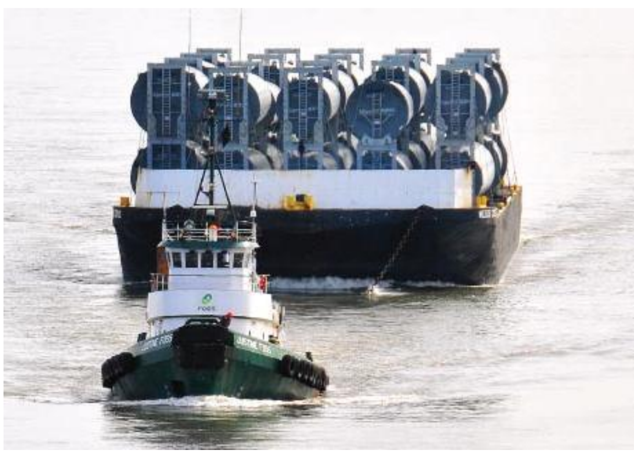

Figure 4.3 Foss Maritime tug and ocean service barge.

Cable lay vessel

Cable lay vessels are often purpose built and export cable installation vessels are typically larger than array cable equivalents. The vessels have a cable carousel with a capacity of up to 7,000t (for export cable laying). The vessel is usually self loading with the cable spooled onto the carousel straight from the manufacturing facility. Examples include Van Oord’s *Nexus*, CT Offshore’s *CLV Sia* and VBMS’s *Stemat Spirit*. Multipurpose vessels may also be fitted out for cable laying but their port requirements are similar to purpose-built cable installation vessels.

Table 4.5 Principal particulars of a cable lay vessel.

Principal particulars	
Length	40 to 145m
Beam	9 to 32m
Draft	3 to 9m
Air draft	< 25m

Figure 4.4 Cable lay vessel Van Oord *Nexus*.

Offshore heavy-lift derrick

Heavy lift derricks are capable of lifting loads of 1,000t to 8,000t. A feeder vessel (a general cargo vessel or barge) may be used alongside the heavy lift vessel to feed components and maximize the time of the main vessel on site. Heavy lifts are used during the installation of large components such as foundations or substations. Examples include Scaldis Salvage and Marine's *Rambiz*, and Seaway Heavy Lifting's *Oleg Strashnov* and *Stanislav Yudin*.

Table 4.6 Principal particulars of an offshore heavy-lift derrick.

Principal particulars	
Length	100 to 185m
Beam	20 to 72m
Draft	4 to 13m
Air draft	20 to 50m

Figure 4.5 Offshore heavy-lift derrick *EP Paup*.

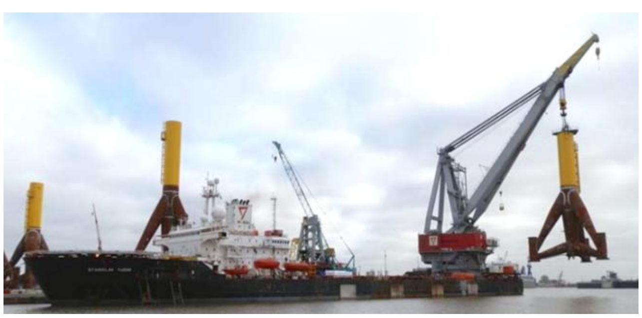

Figure 4.6 Offshore heavy-lift derrick *Stanislav Yudin*.

4.2. Blade manufacturing

Import and storage of materials and components

The main materials used in the production of blades are glass or carbon fiber mats, resins and adhesives. There are also structural components, particularly for the blade root.

All materials can be transported by standard heavy goods vehicles (HGVs) or sea-borne containers.

Mats and structural components are typically stored in standard warehousing. Some manufacturers use mats that are pre-impregnated with resin ("pre-preg"), for which refrigerated storage is required. Resins and adhesives are stored in suitable liquid bulk tanks near the main production site.

Manufacturing

Next generation blades have a length of up to 100m with a chord (width) up to 10m. A manufacturing facility must have space to accommodate one or more moulds and a paint shop, and allow the easy and safe maneuvering of complete blades.

Production and coating of the blades needs to be undertaken in strictly controlled environments.

Storage of finished goods

Due to the need to balance stable year-round production rates and high installation rates during the summer, a blade manufacturer needs to have sufficient storage for at least half of the facility's annual production capacity.

Blades are stored in bespoke frames that can be stacked two or more high. Blades are laid out so that cranes or reach-stackers can access them easily.

Blades are stored with waterproof protection at the root but, otherwise, no weather protection is required.

Export of finished goods

The size of next-generation offshore wind blades means it is not possible to move them by road. If a manufacturer chooses to produce smaller blades for the onshore market then road transport is needed.

Turbine blades have a relatively low mass for their size and therefore do not need high load-bearing quayside or cranes for handling.

Blades are transported in their storage frames using specialist heavy-lift vessels. Such vessels typically have onboard tandem cranes that can be used for loading but, if not, two quayside cranes can be used.

It is unlikely that a dedicated berth will be required as movements will be booked in advance and there will be some flexibility about timing.

If necessary, blades can be transferred from the site using a shallow-drafted barge to a deeper water export berth. Although this will involve double handling the units, it may be a more cost effective use of expensive quayside infrastructure.

Table 4.7 lists the optimal port requirements for a manufacturing facility with capacity to supply blades for 100 turbines per year. Figure 4.7 shows an example of a purpose-built offshore wind blade factory.

Table 4.7 Optimal blade manufacturing port parameters (100 sets per year).

Category	Parameter	Optimal requirement
Water access	Horizontal clearance	25m
	Air draft	20m
	Vessel draft	9m
Waterfront site	Total area	222,500m^2 (55 acres)
	Ground bearing pressure	2 t/m^2
	Round-the-clock operation	No
Quay	Length	200m
	Accommodate jack-up vessels	No
	Quayside ground strength (crane footprint and lay-down areas)	5 t/m^2
	Reinforced quayside area (crane footprint and lay-down areas)	1,000 m^2
On-site storage	Storage space - open air	125,000 m^2
	Storage space - enclosed area	0
Road access	Standard truck	Yes
	Oversize truck	Yes
Rail access	Rail access	No
Utilities	Electrical service - rating	Yes
	Process water consumption	Yes
	Gas utility connection	Yes

Figure 4.7 The Senvion offshore wind blade factory (foreground) in Bremerhaven, Germany. The factory is in the foreground; behind it is a staging area for Adwen (formerly Areva) turbines and at the top of the picture is the Weserwind foundation factory.

4.3. Generator manufacturing

Import and storage of materials and components

All the materials and subassemblies for a generator facility are small enough to be transported by standard HGVs or sea-borne containers.

Sensitive components need to be stored in a climate controlled warehousing

Manufacturing

A generator facility typically has a several production lines, but it may be built in a phases to allow a measured ramp-up in capacity.

The first phase of development would include the development of component storage warehousing and logistics areas.

The facility will probably use gantry cranes to move semi-finished and finished components.

Storage of finished goods

All completed generators would need to be stored indoors in controlled conditions. As a facility feeds a nacelle assembly facility, storage is only required as a buffer to the full loading of a vessel.

Export of finished goods

Ideally, the facility is co-located with a nacelle assembly facility so completed units are moved between sites as required, using self-propelled modular transporters (SPMTs).

If the generators are manufactured away from the turbine assembly facility, they are transported in frames, using specialist heavy lift vessels.

It is unlikely that a dedicated berth will be required as movements will be booked in advance and there will be some flexibility over timing.

If necessary, generators can be transferred from the site using a shallow-drafted barge to a deeper water export berth, although this will entail double handling the units.

Road transport is not possible for completed direct drive generators because of the size of units.

Table 4.8 lists the optimal port requirements for a manufacturing facility with capacity to supply generators for 100 turbines per year.

Table 4.8 Optimal generator manufacturing port parameters (100 units per year).

Category	Port characteristic	Optimal Requirement
Water access	Horizontal clearance	35m
	Air draft	15m
	Vessel draft	5m
Waterfront site	Total area	70,000 m^2 (17 acres)
	Ground bearing pressure	5 t/m^2
	Round-the-clock operation	No
Quay	Length	200m
	Accommodate jack-up vessels	No
	Quayside ground strength (crane footprint and lay-down areas)	10 t/m^2
	Reinforced quayside area (crane footprint and lay-down areas)	1,000 m^2
On-site storage	Storage space - open air	0
	Storage space - enclosed area	0
Road access	Standard truck	Yes
	Oversize truck	No
Rail access	Rail access	No
Utilities	Electrical service - rating	Yes
	Process water consumption	Yes
	Gas utility connection	Yes

4.4. Nacelle assembly

Import and storage of materials and components

Large electro-mechanical or structural subassemblies, such as the generator, drive shaft, bed plate and hub are typically imported as project cargo by specialist heavy lift vessels (unless the nacelle assembly facility is clustered with the production facilities for any of these components)

The largest structural components, such as the bedplate and hub, have masses of up to 60t.

Smaller subassemblies and components are imported by standard HGVs or sea-borne containers.

Structural components may be stored outside but electro-mechanical subassemblies are stored in climate-controlled warehousing

Turbine suppliers typically prefer a just-in-time logistics model so there is no need to stockpile sub-assemblies and components.

Manufacturing

Nacelles are assembled using a production line, with an emphasis on lean processes. Volumes are unlikely to require a moving production platform (although this is used on some onshore turbine designs) so units are moved around the facility using SPMTs or cranes.

The site also need mechanical and electrical test facilities to ensure nacelles are operating correctly before being despatched.

Storage of finished goods

Due to the need to balance stable year-round production rates and high installation rates during the summer, a turbine supplier needs to have sufficient storage for at least half of the facility's annual production capacity.

With transport frames and weatherproof covers at sensitive areas, units can be stored outdoors.

Export of finished goods

The size of next-generation offshore wind nacelles means it is not possible to move them by road. A manufacturer may choose to produce smaller onshore units for the local market, in which case road transport may be possible.

Complete offshore wind nacelles have a mass of several hundred tons so high load bearing quayside is required for export.

Nacelles are typically transported in their storage frames. using specialist heavy lift vessels. Such vessels typically have onboard cranes that can be used for loading but, if not, suitable onshore quayside cranes can be used. If necessary, nacelles could be transferred from the site using a shallow-drafted barge to a deeper water export berth, although this will entail double handling the units.

It is unlikely that a dedicated berth is required as movements will be booked in advance and have some flexibility about timing.

Table 4.9 lists the optimal port requirements for a manufacturing facility with capacity to supply 100 nacelles per year. Figure 4.8 shows an example of a purpose-built offshore wind nacelle assembly facility.

Table 4.9 Optimal nacelle assembly port parameters (100 units per year).

Category	Port characteristic	Optimal Requirement
Water access	Horizontal clearance	25m
	Air draft	20m
	Vessel draft	9m
Waterfront site	Total area	100,000m^2 (25 acres)
	Ground bearing pressure	10t/m^2
	Round-the-clock operation	Yes
Quay	Length	300m
	Accommodate jack-up vessels	No
	Quayside ground strength (crane footprint and lay-down areas)	20 t/m^2
	Reinforced quayside area (crane footprint and lay-down areas)	1,500m^2
On-site storage	Storage space - open air	10,500m^2
	Storage space - enclosed area	0
Road access	Standard truck	Yes
	Oversize truck	No
Rail access	Rail access	No
Utilities	Electrical service - rating	Yes
	Process water consumption	Yes
	Gas utility connection	Yes

Figure 4.8 Alstom’s offshore wind generator manufacturing assembly facility in Saint Nazaire, France.

4.5. Tower manufacturing

Import and storage of materials and components

Flat steel plate is delivered in various thicknesses to the facility. Depending on the capability of the supplier, plate can be up to 14m long.

Depending on the location of the subsupplier, plate can be delivered to the site by specialist HGVs or as project cargo by sea.

Other components such as flange rings and internal components (like doors, platforms, ladders and lifts) is supplied as complete or semi-finished sub-assemblies by road or as project cargo.

Coatings are typically delivered by road transport in drums or tanks.

Plate can be stored outdoors but some internal components may need to be kept in standard warehousing

Manufacturing

Depending on the strategy of the manufacturer, the plate may be delivered to the facility in rough cut form or with the edges prepared and shaped ready for welding and rolling. A facility receiving rough cut plate has additional areas for these activities.

Once the plate is prepared, it is rolled and welded into ‘cans’ which are then welded together using submerged arc welding to form ‘sections’. There are typically three sections for a complete offshore wind turbine tower.

Sections have flanges attached and doors cut out. They are then washed, shot blasted and spray painted with a weather proof coating.

Internal components are then installed.

Storage of finished goods

Due to the need to balance stable year-round production rates and high installation rates during the summer, tower suppliers need to have sufficient storage for at least half of the facility’s annual production capacity

With weather proof covers at the ends, units can be stored outdoors

Export of finished goods

The tower is transported in sections. These are usually bolted together at the construction staging ports and installed with a single offshore lift.

The size of next-generation offshore wind towers means it is not possible to move them by road. A manufacturer may also choose to produce smaller onshore units for the local market, in which case road transport may be possible.

Finish sections have a mass of several hundred tons so high load bearing quayside is required for export. Sections are transported in their storage frames. They are typically transported using specialist heavy lift vessels. Such vessels typically have onboard cranes that can be used for loading but, if not, suitable quayside cranes can be used.

If necessary, nacelles can be transferred from the site using a shallow-drafted barge to a deeper water export berth, although this entails double handling the units..

It is unlikely that a dedicated berth is needed as movements will be booked in advance and there is some flexibility over timing.

Table 4.10 lists the optimal port requirements for a tower manufacturing facility with capacity to supply 100 turbines per year. Figure 4.9 shows an example of an operational offshore tower facility.

Table 4.10 Optimal tower manufacturing port parameters (100 units per year).

Category	Port characteristic	Optimal requirement
Water access	Horizontal clearance	25m
	Air draft	20m
	Vessel draft	9m
Waterfront site	Total area	150,000m^2 (37.1 acres)
	Ground bearing pressure	5 t/m^2
	Round-the-clock operation	No
Quay	Length	300m
	Accommodate jack-up vessels	No
	Quayside ground strength (crane footprint and lay-down areas)	10 t/m^2
	Reinforced quayside area (crane footprint and lay-down areas)	1,500 m^2
On-site storage	Storage space - open air	75,000 m^2
	Storage space - enclosed area	0
Road access	Standard truck	Yes
	Oversize truck	Yes
Rail access	Rail access	No
Utilities	Electrical service - rating	Yes
	Process water consumption	Yes
	Gas utility connection	Yes

Figure 4.9 Ambau's offshore tower factory in Cuxhaven, Germany.

4.6. Foundation manufacturing

Import and storage of materials and components

The steel for jacket foundations is typically delivered to the site pre-rolled into tubulars.

Depending on the location of the subsupplier, tubulars can be delivered to the site by specialist HGVs or as project cargo by sea.

Secondary steel components such as platforms, anodes, and cable tubes are supplied as complete or semi-finished subassemblies by road or as project cargo.

Tubular sections can be stored outdoors but some secondary steel components may be kept in standard warehousing.

Manufacturing

Depending on the strategy of the manufacturer, the tubulars may be delivered cut to size with edges prepared for welding. A facility receiving unprepared tubulars has additional areas for these activities.

Ideally, jackets are fabricated on a production line with units moved through the facility by gantry cranes.

Once the main structure is complete, it is shot blasted and spray painted with a weather-proof coating. Secondary steel items are then attached.

The jacket is not up-ended until it has been taken out of the factory

Storage of finished goods

Due to the need to balance stable year-round production rates and high installation rates during the summer, foundation suppliers need to have sufficient storage for at least half of the facility's annual production capacity.

Units can be stored outdoors

Export of finished goods

A complete jacket has a mass of several hundred tons so a high load-bearing quayside is required

Currently, jackets are exported by barge using onshore cranes. Units are fixed to the barge and then towed away. Suppliers may choose to use barges as floating storage, in which case the land storage requirement is reduced.

A dedicated berth may be required as the supplier aims to line up units near the quayside to avoid double handling, although this is not essential.

Table 4.11 lists the optimal port requirements for a manufacturing facility with capacity to supply 100 foundations per year. Figure 4.10 shows an operational foundation manufacturing facility.

.

Table 4.11 Optimal foundation manufacturing and staging port parameters (100 units per year).

Category	Port characteristic	Optimal requirement
Water access	Horizontal clearance	35m
	Air draft	85m
	Vessel draft	5m
Waterfront site	Total area	220,000m^2 (55 acres)
	Ground bearing pressure	5t/m^2
	Round-the-clock operation	No
Quay	Length	125m
	Accommodate jack-up vessels	No
	Quayside ground strength (crane footprint and lay-down areas)	20 t/m^2
	Reinforced quayside area (crane footprint and lay-down areas)	1,250m^2
On-site storage	Storage space - open air	120,000m^2
	Storage space - enclosed area	0
Road access	Standard truck	Yes
	Oversize truck	No
Rail access	Rail access	No
Utilities	Electrical service - rating	Yes
	Process water consumption	Yes
	Gas utility connection	Yes

Figure 4.10 Smulders' offshore wind foundation factory in Hoboken, Belgium.

4.7. Submarine cable manufacturing

Import and storage of materials and components

Submarine cable manufacturers either have on-site core extrusion facilities or import them from in-house or external suppliers.

All the materials for a cable manufacturing facility (copper strand, cladding and extrusion material) can be transported by standard HGVs or by sea-borne containers.

There are no special material storage requirements other than the need for sufficient covered warehousing space.

Manufacturing

The production line process is generally laid out in long horizontal bays. Cables and component materials are moved around the site via carousels and forklift trucks.

Cable extrusions are likely to be supplied from external hoppers on the outside of the main factory.

The facility uses gantry cranes to move semi-finished and finished components.

Storage of finished goods

Finished cables are stored on large capacity carousels inside and/or outside the factory.

Cable factories can store multiple lengths of finished product on a single carousel. Product is spooled onto a particular carousel with a planned off-take running sequence.

Export of finished goods

Finished cable is spooled from the manufacturing facility directly onto a cable lay vessel or barge.

Due to bend radius restrictions, many cable facilities use spool tracking on the quayside which can extend via a gantry out into the sea.

Table 4.12 lists the optimal port requirements for a cable manufacturing facility with capacity to supply 150km of cable per year. Figure 4.11 shows an operational cable manufacturing facility.

Table 4.12 Optimal cable manufacturing port parameters (150km per year)

Category	Port characteristic	Optimal requirement
Water access	Horizontal clearance	28m
	Air draft	30m
	Vessel draft	6m
Waterfront site	Total area	90,000m^2 (22 acres)
	Ground bearing pressure	2 t/m^2
	Round-the-clock operation	No
Quay	Length	125m
	Accommodate jack-up vessels	No
	Quayside ground strength (crane footprint and lay-down areas)	N/A
	Reinforced quayside area (crane footprint and lay-down areas)	N/A
On-site storage	Storage space - open air	0
	Storage space - enclosed area	0
Road access	Standard truck	Yes
	Oversize truck	No
Rail access	Rail access	No
Utilities	Electrical service - rating	Yes
	Process water consumption	Yes
	Gas utility connection	Yes

Figure 4.11 Prysmian's high voltage cable factory in Pikkala, Finland.

4.8. Substation manufacturing

Import and storage of materials and components

Large quantities of owner-furnished equipment, primarily power electronics equipment, arrive by truck, rail barge, or ship.

Steel plate and other raw materials and supplies used in shipbuilding arrive by truck, rail, barge or ship.

Manufacturing

Substation manufacturing, whether conventional or self-installing (jack-up), is analogous to shipbuilding and offshore oil and gas platform fabrication. Large steel modules are fabricated, with complex systems all being integrated. These systems include electrical, piping, climate control, fire suppression, personnel safety and overnight personnel accommodation.

Final assembly requires heavy crane lifts (hundreds of tons) and precise joining of large modules.

Conventional substations can be built on quayside that is reachable by a heavy lift derrick.

Self-installing substations are ideally be built in a dry dock. Alternatively, they can be built on a quayside with the legs installed after launching.

Storage of finished goods

There is generally no requirement to store substations. Once completed the finished substation is deployed to the wind farm, provided there is a suitable weather window. Some heavy-lift derricks can only operate in relatively calm sea conditions and this may require short-term storage space.

Export of finished goods

A self-erecting substation platform is integrated into a barge and is therefore towed by tugs to its final location on its own hull.

Conventional substations are typically lifted by a heavy-lift derrick and transported to the final site on a barge. Table 4.13 lists the optimal port requirements for a manufacturing facility with capacity to supply two substations per year. Figure 4.12 and Figure 4.13 show operational yards with characteristics suitable for a substation manufacturing facility.

Table 4.13 Optimal substation manufacturing port parameters (two units per year)

Activity	Vessel type	Dry dock	Manufacturing capability
Conventional substation	Offshore heavy lift crane barge	Not required	Ability to construct 30m (length) x 25m (beam) x 20 m (height) structure with large quantities of complex owner-furnished power electronics equipment and typical maritime electrical, piping, fire suppression and safety systems A covered fabrication hall is preferred Completed high voltage AC units are 800t to 2,500t
Self-installing substation	Tugs for towing Channel requirements: • 7m depth • 50m channel width • Unrestricted air draft	50 m length x 50 m beam	Same requirements as conventional system, with additional requirement to integrate a jack-up system comprising 50 to 75m lattice tower legs or tubular legs and hydraulic rack-and-pinion or pin-and-hole drive system

Figure 4.12 Heerema's yard in Hartlepool, UK during the fabrication of two conventional substations for the Sheringham Shoal wind farm in the UK.

Figure 4.13. Keppel Verolme's main dock in Rotterdam, Netherlands during the manufacturing of the self-Installing substation for the Global Tech 1 wind farm in Germany.

4.9. Construction staging

Import and storage of materials and components

Unless the construction port is clustered with manufacturing facilities, then towers, blades and nacelles are imported to the site.

These components are typically transported general cargo vessels. Such vessels typically have onboard cranes that are for unloading but, if not, suitable quayside cranes can be used.

Storage of finished goods

Developers face high daily projects costs during the construction phase with multiple, high cost charters and larger teams of crew and technicians. As such, it is standard practice to import turbine components to the construction port before the start of offshore activity. This ensure that delays in the supply chain do hold up construction activity

Units may be stacked closely but still need to be individually accessible by cranes or reach stackers

Export of finished goods

Turbine components are moved to a staging area near the quayside, in preparation for loading onto the installation vessel.

Towers sections are assembled to form full towers with installation of power take-off equipment for some models. Blades may be attached to rotor hubs in some cases although this will become less common as rotor diameters increase.

Next generation turbines have been designed to limit the amount of offshore commissioning work. Instead a significant amount of pre-commissioning is undertaken onshore,

Components are then be moved to the loading quayside. As the tower and nacelle may both have a mass of several hundred tons, the quayside needs to have high a load bearing capacity.

Turbines are installed using a jack-up vessel. These vessels will come alongside the quay wall and lower their legs to give a stable platform during loading. The sea bed around the quayside (and the quayside itself) therefore needs to be suitable for repeated jacking-up operations.

Components are then loaded on to the jack-up vessel for installation. The jack-up vessel will typically use its own crane to complete this operation.

Table 4.14 lists the optimal port requirements for a construction staging facility with capacity to handle 100 turbines per year. Figure 4.14 shows an operational facility with suitable characteristics.

Table 4.14 Optimal construction staging port parameters (100 sets per year).

Category	Port characteristic	Optimal requirement
Water access	Horizontal clearance	110m
	Air draft	130m
	Vessel draft	8m
Waterfront site	Total area	200,000m^2 (50 acres)
	Ground bearing pressure	10t/m^2
	Round-the-clock operation	Yes
Quay	Length	200m
	Accommodate jack-up vessels	Yes
	Quayside ground strength (crane footprint and lay-down areas)	25t/m^2
	Reinforced quayside area (crane footprint and lay-down areas)	2,000m^2
On-site storage	Storage space - open air	80,000m^2
	Storage space - enclosed area	0
Road access	Standard truck	Yes
	Oversize truck	No
Rail access	Rail access	No
Utilities	Electrical service - rating	Yes
	Process water consumption	Yes
	Gas utility connection	Yes

Figure 4.14 Construction staging at Belfast, Northern Ireland during the construction of the UK West of Duddon Sands wind farm.

5. Port evaluation

This section presents the findings from our evaluation of 10 ports for readiness to support the following seven offshore wind activities:

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing
- Foundation manufacturing
- Submarine cable manufacturing
- Construction staging

Table 5.1 summarizes the port evaluations. The readiness of each port was rated green, yellow, orange or red for each of the seven offshore wind activities. The ratings are defined in Table 3.1. Sites rated green or yellow have the highest level of port readiness and were considered for additional implementation analysis (see Section 6). Sites rated red have a hard constraint such as inadequate space or bridge interference for inbound or outbound vessels. Sites rated orange have a lower readiness level and could be analyzed for implementation in a future study.

Norfolk Southern Lamberts Point was rated red for all activities for two reasons:

1. Its extensive rail infrastructure is generally incompatible with offshore wind activities, and
2. The port is thriving as a vessel-to-rail transshipment terminal, serving a critical function for the region.

Section 5.11 presents an evaluation of Virginia's commercial shipyard readiness to manufacture offshore substations.

Table 5.1 Summary evaluation of the ports.

Green = Site is suitable with few or no upgrades
Yellow = Site is suitable with upgrades
Orange = Site is suitable with major improvements
Red = Site is unsuitable
See Table 3.1 for rating definitions

	Portsmouth Marine Terminal	Newport News Marine Terminal	Cape Charles Harbor	Norfolk Southern Lamberts Point	Peck Marine Terminal	BASF James City	Gravel Neck	Virginia Renaissance Center	Steel Street Chesapeake	BASF Portsmouth
Blade manufacturing	Y	Y	O	R	Y	O	O	Y	O	Y
Generator manufacturing	Y	Y	O	R	Y	O	O	O	O	Y
Nacelle assembly	Y	Y	O	R	Y	O	O	R	O	Y
Tower manufacturing	Y	Y	O	R	Y	O	O	R	O	Y
Foundation manufacturing	Y	Y	O	R	R	R	R	R	R	Y
Submarine cable manufacturing	G	G	O	R	G	O	O	G	O	G
Construction staging	Y	Y	R	R	R	R	R	R	R	Y

5.1. Portsmouth Marine Terminal

Readiness evaluation

Portsmouth Marine Terminal is a state-owned port on the eastern shore of the Elizabeth River. It has enough space to support multiple offshore wind activities. No infrastructure upgrades would be required to support cable manufacturing. It could accommodate each of the other activities with some upgrades.

Because the site was built on reclaimed land, we have geotechnical concerns for all activities except cable manufacturing. We conclude that ground strength investigations will be needed and improvements are likely to be required. We are concerned that the site layout would prevent the maneuvering of the longest blades. We are uncertain whether the sea bed at the quayside is suitable for jack-up vessels, which would be required for construction staging.

Table 5.2 provides an overview of the port. The evaluation is summarized in Table 5.3. Figure 5.1 shows an aerial photograph of the site.

Table 5.2 Overview of the readiness of Portsmouth Marine Terminal.

Category	Comments
Location	Eastern shore of lower Elizabeth River
Size	1,161,000 m^2 (287 acres)
Navigational constraints	Unrestricted deep water access
Commercial overview	Publicly owned Partially occupied by container shipping operations
Strengths	Excellent vessel, rail and road access
Weaknesses	Layout of existing buildings
Unknowns	Suitability for jacking up
Non-technical issues	No site exclusivity
Insights	Manufacturing may conflict with existing container shipping business Large area expected to be available as of 2016 This site could operate as a regional offshore wind

Non-technical considerations

Portsmouth Marine Terminal is used as surge capacity for to the nearby international container terminal. The site changed use less than two years ago.

Using this site for manufacturing or leasing the site on an exclusive basis do not appear to be part of the current business plan.

A strong local workforce is in place.

Table 5.3 Readiness of Portsmouth Marine Terminal for different offshore wind activities.

Activity	Conclusion
Blade manufacturing	Concern about ground bearing strength Concerns over on-site maneuvering of blades
Generator manufacturing	Concern about ground bearing strength
Nacelle assembly	Ground strength improvements needed
Tower manufacturing	Ground strength improvements needed
Foundation manufacturing	Ground strength improvements needed
Submarine cable manufacturing	
Construction staging	Ground strength improvements needed Suitability for jacking up is unknown

Figure 5.1 Aerial photograph of Portsmouth Marine Terminal. Red line shows the site boundary.

5.2. Newport News Marine Terminal

Readiness evaluation

Newport News Marine Terminal is a state owned port on the north bank of the James River. It is currently used for car storage. No infrastructure upgrades would be required to support cable manufacturing. Other activities could be accommodated here with some upgrade. Significant lay-down area is available at Pier C, which would be suitable for blade storage. The neighboring coal storage facility is watered four times per day.

Ground strength investigations and subsequent improvements are likely to be required for most functions. Specifically, we have concerns over the load-bearing capacity of the piers. Also, existing buildings on the site may constrain the maneuvering of larger items such as towers, blades and foundations. We are uncertain whether the sea bed at the quayside is suitable for jacking up vessels, which would be required for construction staging.

Table 5.4 provides an overview of the port. Table 5.5 summarizes the evaluation. Figure 5.2 shows an aerial photograph of the site.

Table 5.4 Overview of the readiness of Newport News Marine Terminal

Category	Comments
Location	North bank of James River
Size	670,000 m^2 (165 acres)
Navigational constraints	Unrestricted deep water access
Commercial overview	Publicly owned Occupied by car import business
Strengths	Excellent vessel, rail and road access
Weaknesses	Aging infrastructure
Unknowns	Suitability for jacking up Ground strength
Non-technical issues	Site currently occupied
Insights	Manufacturing is not consistent with business model Neighboring coal facility is a concern

Non-technical considerations

Newport News Marine Terminal is currently used as a car import terminal. Offshore wind manufacturing would potentially displace this activity.

Using this site for manufacturing or leasing the site on an exclusive basis do not appear to be part of the current business plan.

A capable local workforce is in place.

Table 5.5 Readiness of Newport News Marine Terminal for different offshore wind activities.

Activity	Conclusion
Blade manufacturing	Concern about ground bearing strength No site exclusivity Existing buildings constrain maneuverability
Generator manufacturing	Concern about ground bearing strength
Nacelle assembly	Load-bearing concerns for piers; unlikely to be usable for heavier components
Tower manufacturing	Load-bearing concerns for piers; unlikely to be usable for heavier components Existing buildings interfere with maneuverability
Foundation manufacturing	Load-bearing concerns for piers; unlikely to be usable for heavier components Existing buildings constrain maneuverability
Submarine cable manufacturing	Few or no upgrade needed
Construction staging	Load-bearing concerns for piers; unlikely to be usable for heavier components Suitability for jacking up is unknown

Figure 5.2 Aerial photograph of Newport News Marine Terminal. Yellow line shows the site boundary. Red line show the boundaries of the two sites.

5.3. Cape Charles Harbor

Readiness evaluation

Cape Charles Harbor is a privately owned port on the eastern shore of Chesapeake Bay. There is an additional larger parcel immediately upland from the port. The waterfront site and the upland site have different owners, both private. Combined the two parcels have enough space to accommodate all of the offshore wind activities. Our evaluation considers both sites together.

No infrastructure upgrade is needed to support cable manufacturing. We conclude that construction staging is restricted by water depth and maneuverability of vessels in the harbor and its approach. To support other offshore wind activities Cape Charles Harbor needs an upgrade to waterside infrastructure and basic ground improvements made. The adjacent concrete plant may create particulates in the air, which can be a problem for offshore wind manufacturing activities.

Table 5.6 provides an overview of the port. Table 5.7 summarizes the evaluation. Figure 5.3 shows an aerial photograph of the site.

Table 5.6 Overview of the readiness of Cape Charles Harbor.

Category	Comments
Location	Eastern shore of Chesapeake Bay
Size	590,000 m^2 (146 acres)
Navigational constraints	Narrow channel maintained by Army Corps
Commercial overview	Privately owned with two owners
Strengths	Large site without overhead constraints
Weaknesses	Infrastructure improvements required
Unknowns	Suitability for jacking up Ground strength
Non-technical issues	Tax incentives available Recruitment of a local workforce may be difficult
Insights	Total acreage with two sites is large enough for a manufacturing cluster May be suitable for barge–serviced manufacturing cluster once site improvements are made.

Non-technical considerations

Cape Charles Harbor is as an enterprise zone for tax, meaning that some incentives are available. It is not close to population centers and it may be difficult to attract a local workforce . Land use zoning would need to be changed to accommodate manufacturing.

Table 5.7 Readiness of Cape Charles Harbor for different offshore wind activities.

Activity	Conclusion
Blade manufacturing	Needs new waterside infrastructure Need for basic ground improvements
Generator manufacturing	Needs new waterside infrastructure Need for basic ground improvements
Nacelle assembly	Needs new waterside infrastructure Need for basic ground improvements
Tower manufacturing	Needs new waterside infrastructure Need for basic ground improvements
Foundation manufacturing	Needs new waterside infrastructure Need for basic ground improvements
Submarine cable manufacturing	Few or no upgrade needed
Construction staging	Vessel access (water depth and maneuvering)

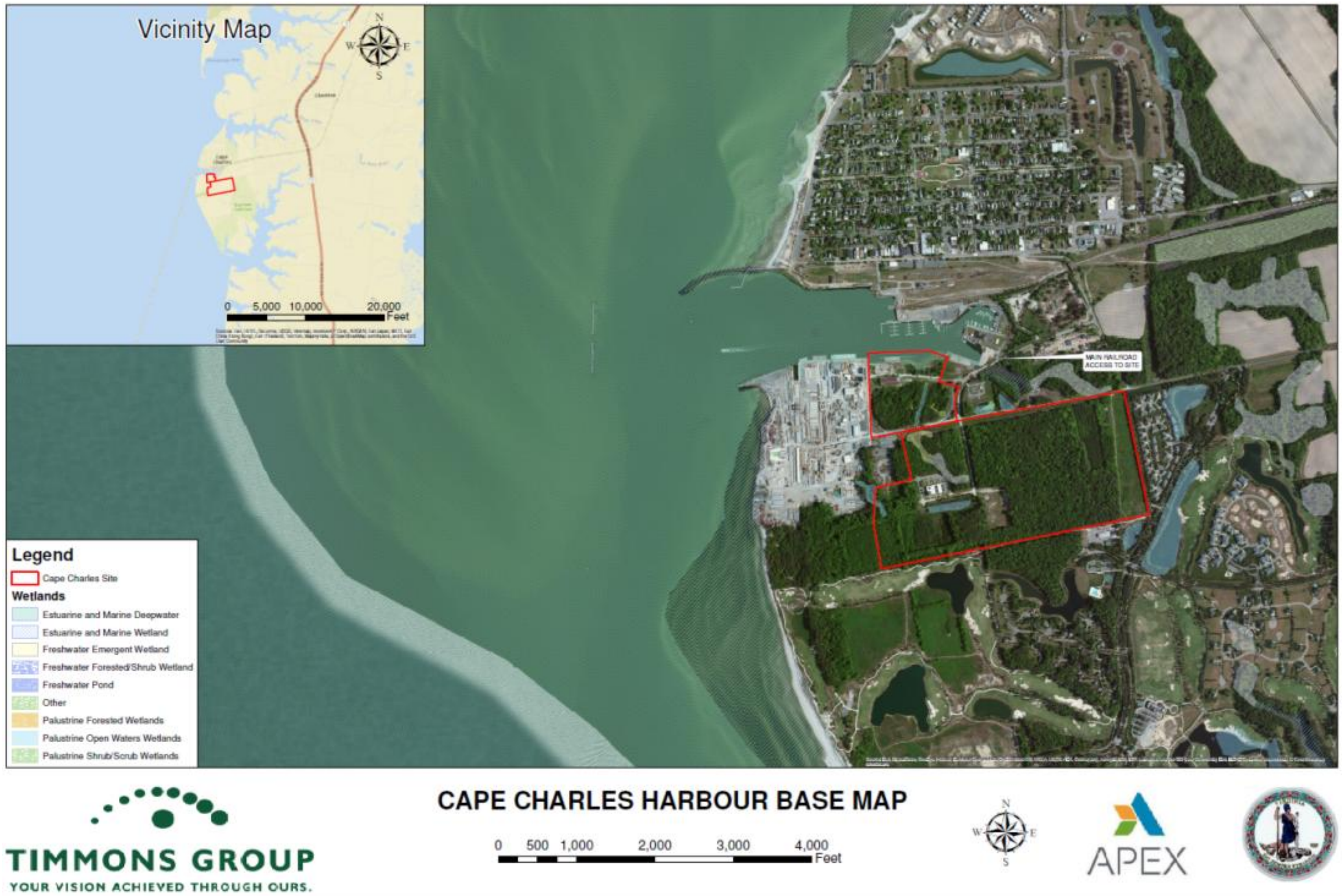

Figure 5.3 Aerial photograph of Cape Charles Harbor. Red line show the boundaries of the two sites.

5.4. Norfolk Southern Lamberts Point

Readiness evaluation

Norfolk Southern Lamberts Point is a privately owned busy port at the confluence of the Lafayette and Elizabeth Rivers. It is a large site and has the space to support most offshore wind activities.

We conclude that to support these activities Norfolk Southern Lamberts Point would need to remove a significant amount of infrastructure related to the current vessel-to-rail transhipment activities.

Table 5.8 provides an overview of the port. Table 5.9 summarizes the evaluation. Figure 5.4 shows an aerial photograph of the site.

Table 5.8 Overview of the readiness of Norfolk Southern Lamberts Point.

Category	Comments
Location	Eastern shore Elizabeth River
Size	473,000 m2(117 acres)
Navigational constraints	Deep water access
Commercial overview	Privately owned
Strengths	Excellent vessel access Road and rail access Large site
Weaknesses	Existing infrastructure not compatible with offshore wind activities As currently configured, lacks space for lay-down and manufacturing
Unknowns	Little technical data available on this site
Non-technical issues	Robust existing operation that appears unlikely to be displaced
Insights	For offshore wind activities, most existing infrastructure related to vessel-to-rail transhipment would need removed.

Non-technical considerations

Norfolk Southern Lamberts Point is a successful rail to ship hub for break bulk. Coal is a big economic driver so it would be difficult to justify displacing a successful operation.

Table 5.9 Readiness of Norfolk Southern Lamberts Point for different offshore wind activities.

Activity	Conclusion
Blade manufacturing	Conflicts with existing operations Existing infrastructure is incompatible with needs
Generator manufacturing	
Nacelle assembly	
Tower manufacturing	
Foundation manufacturing	
Submarine cable manufacturing	
Construction staging	

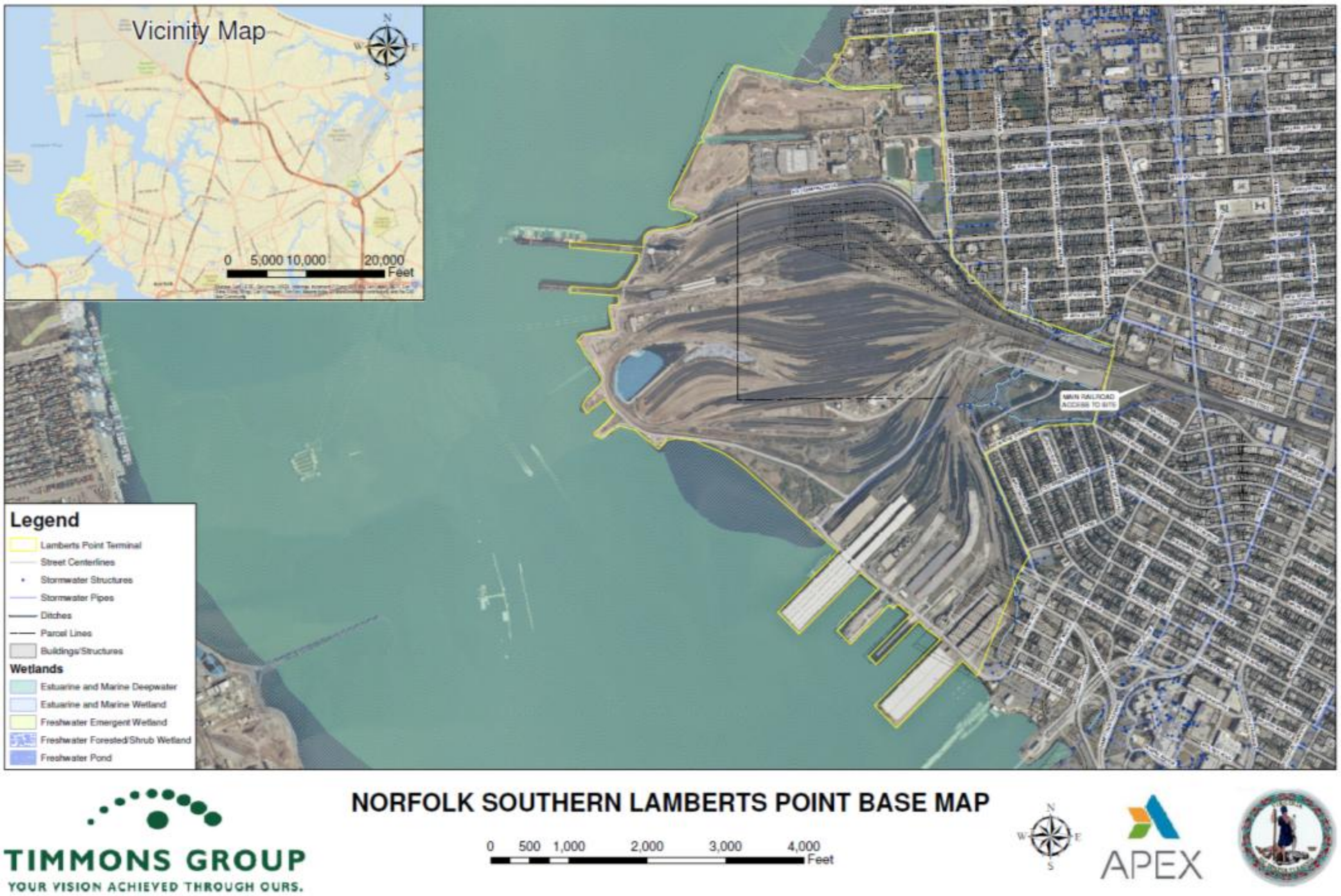

Figure 5.4 An aerial photograph of Norfolk Southern Lamberts Point. Yellow line shows the boundary of the site.

5.5. Peck Marine Terminal

Readiness evaluation

Peck Marine Terminal is a privately owned deep-water port on the southern branch Elizabeth River. The site was formerly a Texaco facility and is currently available.

The Jordan Bridge downstream of the port makes the site unsuitable for foundation manufacturing and construction staging due to air draft restrictions. For submarine cable manufacturing the port requires only requires site clearance. The port's use for other activities would require removal of petrochemical tanks and associated remediation, and extension and strengthening of the waterside infrastructure. There is a storm-water retention pond that may need to be relocated for some activities. The overall land parcel is large enough to support a combination of activities.

Table 5.10 Overview of the readiness of Peck Marine Terminal.

Category	Comments
Location	Southern branch of the Elizabeth River
Size	223,000 m^2 (55 acres)
Navigational constraints	Deep water access
Commercial overview	Privately owned, vacant
Strengths	Large site could support multiple activities Deep water port Waterside infrastructure in place
Weaknesses	Site clearance and remediation required Jordan Bridge precludes some activities
Unknowns	Extent of remediation Capacity of existing waterside infrastructure
Non-technical issues	Good workforce availability
Insights	Potentially a good site without the need for major improvements

Non-technical considerations

Peck Marine Terminal is surrounded by other commercial operations. Attracting a local workforce is not expected to be a problem.

The site is available, although the land use zoning of the site may need to be changed.

We understand that trains often block the access road, which could affect commuter access to the site.

Table 5.11 summarizes the evaluation. Figure 5.5. shows an aerial photograph the site.

Table 5.11 Readiness of Peck Marine Terminal for different offshore wind activities.

<table>
<tr><th>Activity</th><th>Conclusion</th></tr>
<tr><td>Blade manufacturing</td><td rowspan="4">Extension and strengthening of waterside infrastructure
Remove and remediate petrochemical tanks
Remove buildings
Site clearing (potential remediation)</td></tr>
<tr><td>Generator manufacturing</td></tr>
<tr><td>Nacelle assembly</td></tr>
<tr><td>Tower manufacturing</td></tr>
<tr><td>Foundation manufacturing</td><td>Air draft constraint</td></tr>
<tr><td>Submarine cable manufacturing</td><td>Site clearance needed</td></tr>
<tr><td>Construction staging</td><td>Air draft constraint</td></tr>
</table>

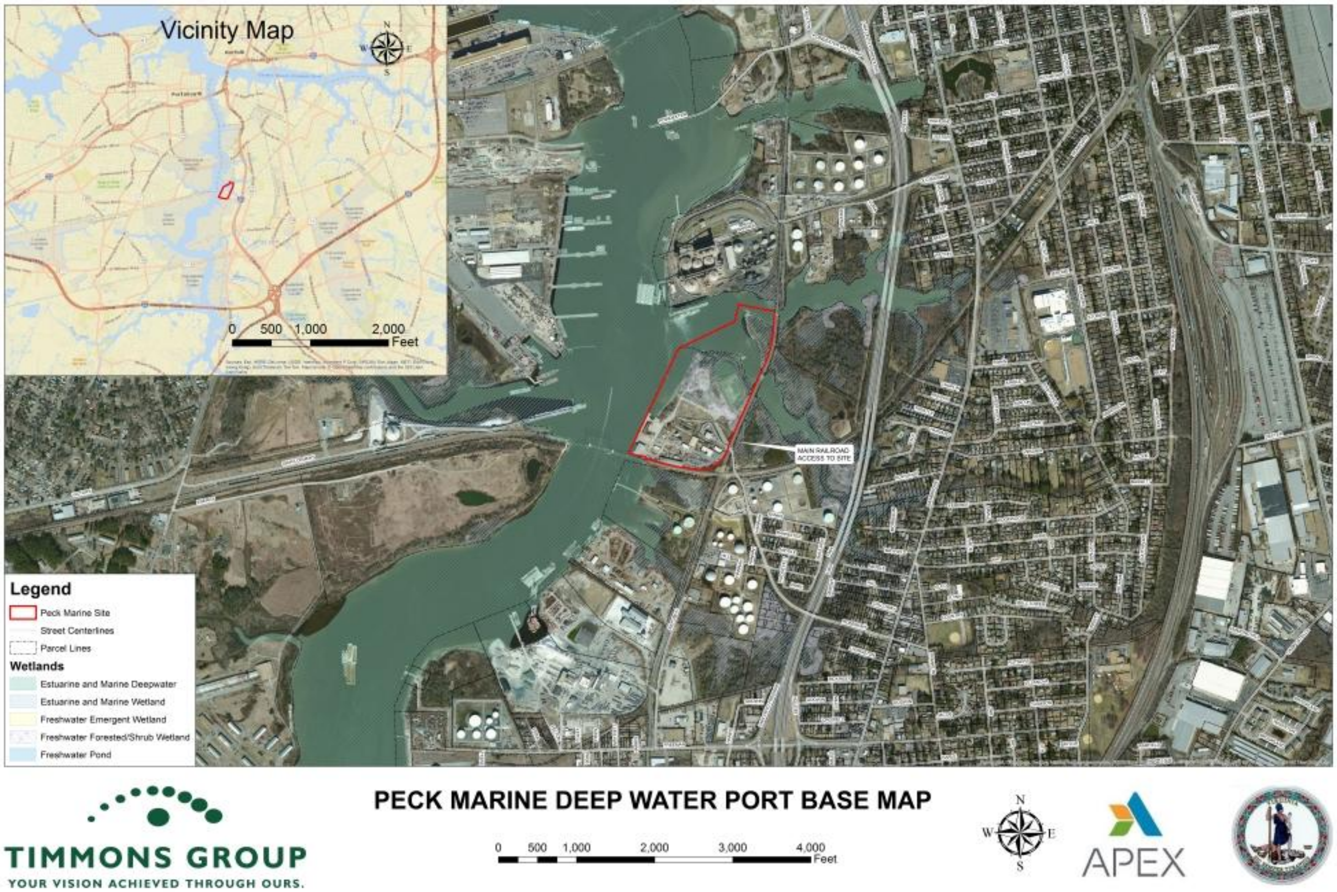

Figure 5.5 Aerial photograph of Peck Marine Terminal. Red line shows the site boundary.

5.6. BASF James City

Readiness evaluation

BASF James City is a privately owned site on the eastern shore of the James River. It is interspersed with wetlands and narrow sections, much of which is textile fibre landfill. The site is vacant and large enough for all offshore wind activities. The air draft restrictions of the James River Bridge, however, mean that it is unsuitable for foundation manufacturing and construction staging.

To support offshore wind activities, significant waterside infrastructure would need to be developed. This would be a bigger challenge than with the other sites considered because the shoreline has steep 3 to 6m bluffs. A new turning basin for large vessels would be needed.

Table 5.12 Overview of the readiness of BASF James City.

Category	Comments
Location	Eastern shore James River
Size	1,214,000 m^2 (300 acres)
Navigational constraints	Improvement dredging required Turning basin required.
Commercial overview	Privately owned, vacant
Strengths	Large site could support multiple activities
Weaknesses	Usable areas are disjointed No waterside infrastructure Improvement dredging needed Shoreline restoration likely to be required 6m bluffs along shoreline
Unknowns	Strength of ground (large areas of textile fibre landfill) Extent of environmental remediation Requirements for shoreline restoration
Non-technical issues	Land use zoning is undergoing a change to mixed use Plans in place to build a river walk
Insights	Site has not had a major use for over a decade

Non-technical considerations

The location of BASF James City may make it difficult to recruit a suitable manufacturing workforce.

The site is available, although the land use zoning of the site is undergoing a change to Mixed Use.

Table 5.13 summarizes the evaluation. Figure 5.6 shows an aerial photograph of the site.

Table 5.13 Readiness of BASF James City for different offshore wind activities.

Activity	Conclusion
Blade manufacturing **Generator manufacturing** **Nacelle assembly** **Tower manufacturing**	Site layout questionable Improvement dredging and turning basin Waterside infrastructure Site clearing Ground improvement and stabilization
Foundation manufacturing	James River Bridge restriction
Cable manufacturing	Site layout questionable Improvement dredging and turning basin Waterside infrastructure Site clearing Ground improvement and stabilization
Construction staging	James River Bridge restriction

Figure 5.6 Aerial photograph of BASF James City. The red line shows the site boundary.

5.7. Gravel Neck

Readiness evaluation

Gravel Neck is a privately owned forested site with wetlands. The site is vacant and large enough for all offshore wind activities and could host a manufacturing cluster.

To support offshore wind activities, significant waterside infrastructure would need to be developed. Improvement dredging would be required and access would need to be improved.

Table 5.14 Overview of the readiness of Gravel Neck

Category	Comments
Location	James River
Size	2,400,000m^2 (590 acres)
Navigational constraints	Improvement dredging required Navigational draft of Tribell Shoal Channel is marginal for vessels
Commercial overview	Privately owned, vacant
Strengths	Large site could support multiple activities
Weaknesses	No waterside infrastructure Improvement dredging needed No road and rail access
Unknowns	Extent of wetlands Limited technical data available
Non-technical issues	
Insights	More attractive Greenfield option than nearby BASF James City

Non-technical considerations

The location of Gravel Neck may make it difficult to recruit a suitable manufacturing workforce.

The site is available and neighbors a nuclear power station which may impose some restrictions.

Table 5.15 summarizes the evaluation. Figure 5.7 shows an aerial photograph of the site.

Table 5.15 Readiness of Gravel Neck for different offshore wind activities.

Activity	Conclusion
Blade manufacturing	Improvement dredging Waterside infrastructure Site clearing (deforestation, wetlands, full green field process) Water and sewer to site
Generator manufacturing	
Nacelle assembly	
Tower manufacturing	
Foundation manufacturing	James River Bridge restriction
Cable manufacturing	Site clearing Water and sewer to site
Construction staging	James River Bridge restriction

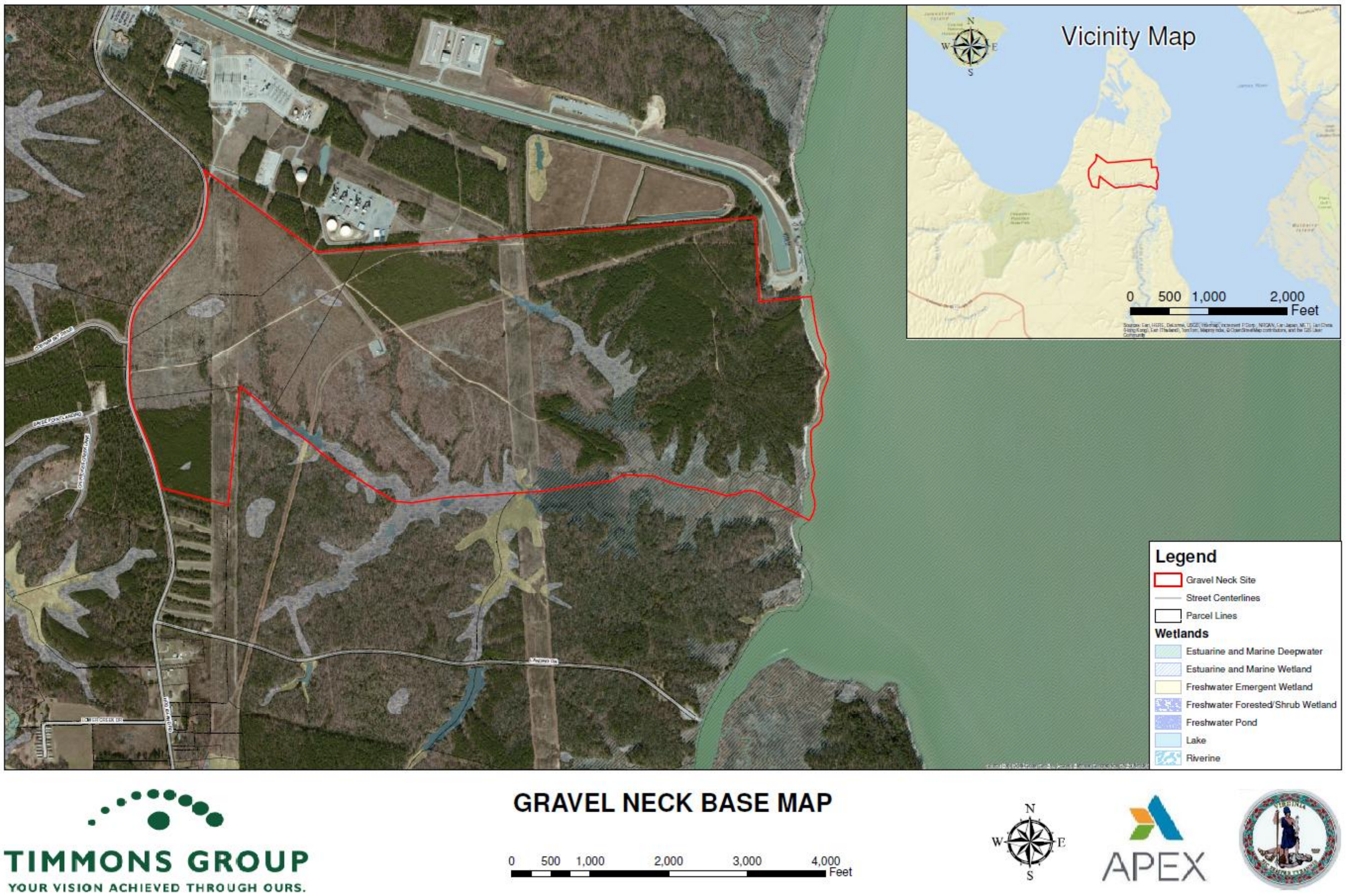

Figure 5.7 Aerial photograph of Gravel Neck. The red line shows the site boundary.

5.8. Virginia Renaissance Center

Readiness evaluation

Virginia Renaissance Center is a privately owned port on the southern shore of the Elizabeth River. It is currently available. There are height restrictions due to three bridges downstream of the site and only barges have access. This rules out foundation manufacturing, construction staging and nacelle assembly. Tower, blade and generator manufacturing could be supported by barge, and cable manufacturing could be accommodated provided that the vessels used can clear the bridges. This site has the strongest potential for blade manufacturing but storage capacity may be the deciding factor.

Improvement dredging alongside the pier as well as some pier improvements will be required to support the barge supported activities.

Table 5.16 Overview of the readiness of Virginia Renaissance Center.

Category	Comments
Location	Southern shore of Elizabeth River
Size	81,000 m^2 (20 acres)
Navigational constraints	Three bridges with a maximum air draft of 20m
Commercial overview	Privately owned, vacant
Strengths	Existing slabs in place from former use as a truck plant Waterside infrastructure in place Rail access
Weaknesses	Barge access only Not enough space for manufacturing cluster
Unknowns	Strength of waterside infrastructure Lack of geotechnical data
Non-technical issues	Difficult to obtain technical site data
Insights	Blade manufacturing is best suited to a barge-serviced port, but the size of this site is marginal for blade manufacturing

Non-technical considerations

Virginia Renaissance Center is owned by property developers the Jacoby Group who envision a manufacturing and logistics park at the site. There are some environmental issues with the site but these are understood and partially remediated.

Table 5.17 summarizes the evaluation. Figure 5.8 shows an aerial photograph of the site.

Table 5.17 Readiness of Virginia Renaissance Center for different offshore wind activities.

Activity	Conclusion
Blade manufacturing	Improvement dredging alongside pier Pier strengthening and improvements
Generator manufacturing	Improvement dredging alongside pier Pier strengthening and improvements
Nacelle assembly	Barge access only
Tower manufacturing	Improvement dredging alongside pier Pier strengthening and improvements
Foundation manufacturing	Clearance problems
Submarine cable manufacturing	Possible provided that vessel can clear Campostella Bridge
Construction staging	Clearance problems

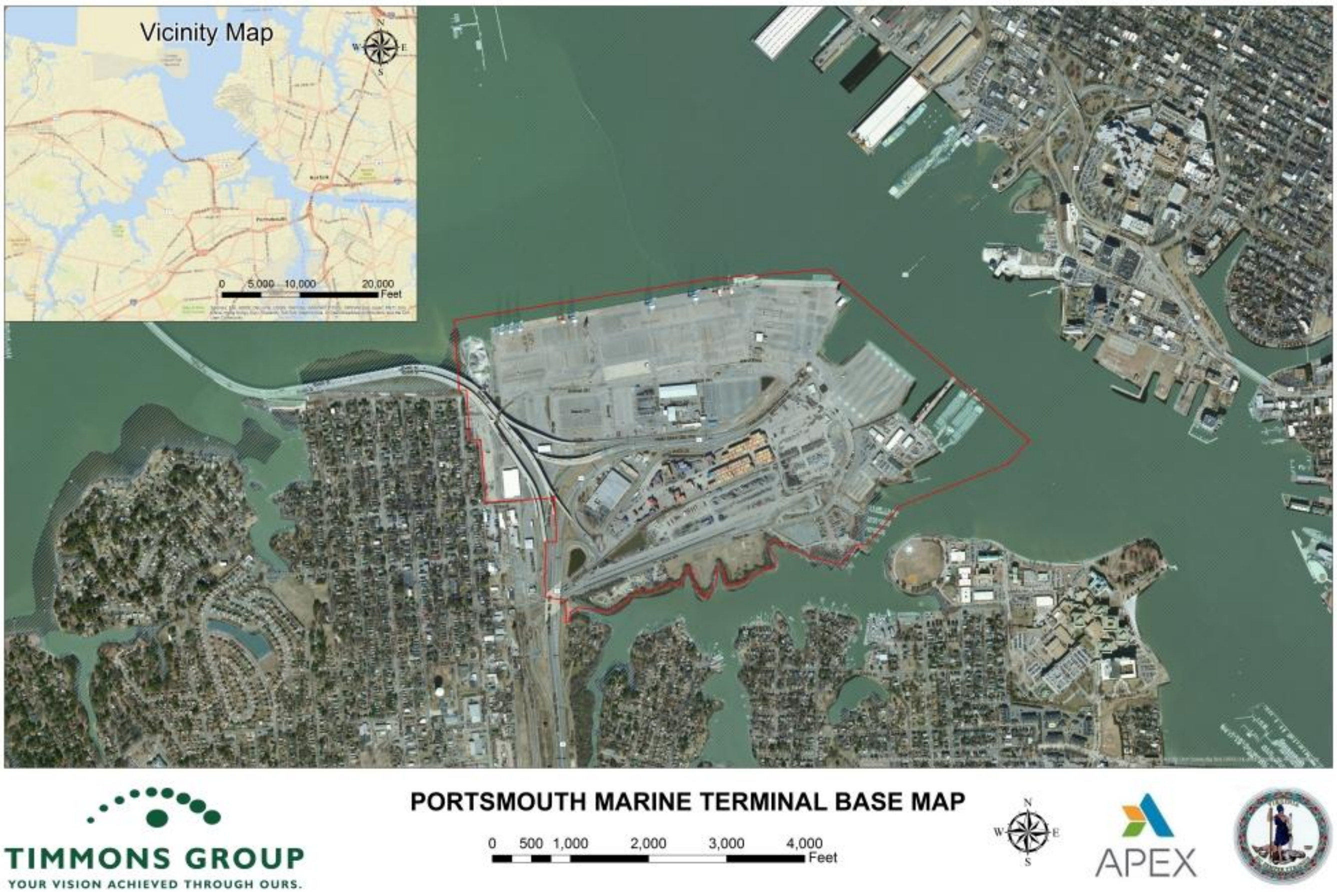

Figure 5.8 Aerial photograph of Virginia Renaissance Center. The red line shows the site boundary.

5.9. Steel Street, Chesapeake

Readiness evaluation

Steel Street Chesapeake is a privately owned busy site with multiple tenants. To support offshore wind activities, significant waterside infrastructure would need to be developed, improvement dredging would be required and vessel access would need to be improved.

Overhead constraints rule out construction staging and jacket fabrication entirely.

Table 5.18 Overview of the readiness of Steel Street Chesapeake

Category	Comments
Location	Elizabeth River
Size	219,000m^2 (54 acres)
Navigational constraints	Improvement dredging required Overhead restriction of 38.1m
Commercial overview	Privately owned, multiple tenants
Strengths	Good length for blades Rail access to property line
Weaknesses	No waterside infrastructure Site clearance required Multiple obstructions including bridges and overhead cables.
Unknowns	Ground strength (anecdotal evidence that it is built on fill)
Non-technical issues	Existing tenants do not require infrastructure improvements or dredging
Insights	Enthusiastic property owners who would consider building on the property.

Non-technical considerations

The owners are very enthusiastic and would consider building on the site. 2 year leases are available for the site.

Table 5.19 summarizes the evaluation. Figure 5.9 shows an aerial photograph of the site.

Table 5.19 Readiness of Steel Street Chesapeake for different offshore wind activities.

Activity	Conclusion
Blade manufacturing	Waterside infrastructure Improvement dredging Site clearing Ground improvements
Generator manufacturing	
Nacelle assembly	
Tower manufacturing	
Foundation manufacturing	Overhead constraints and water depth
Cable manufacturing	Vessel access (draft) Site clearing
Construction staging	Overhead constraints and water depth

Figure 5.9 Aerial photograph of Steel Street Chesapeake. The red line shows the site boundary.

5.10. BASF Portsmouth

Readiness evaluation

BASF Portsmouth is a privately owned site The site has no air draft restrictions. With some new waterside infrastructure and dredging or infill to the main channel, the site would be suitable for all activities. The site would be suitable multiple operations, especially if infill is pursued.

The owner is pursuing environmental clearance from the Virginia Department of Environmental Quality.

Table 5.20 Overview of the readiness of BASF Portsmouth.

Category	Comments
Location	Elizabeth River
Size	178,000 m^2 (44 acres)
Navigational constraints	Unrestricted to South pier
Commercial overview	Privately owned Available for sale or long-term lease
Strengths	Main channel has excellent vessel access Site is large enough for a manufacturing cluster
Weaknesses	No waterside infrastructure Accessing channel requires improvement dredging or major infill
Unknowns	Environmental remediation requirements
Non-technical issues	Part of site has a long term lease for coal use
Insights	Potential to become an offshore wind super-port, but would require a major infill project and new waterside infrastructure

Non-technical considerations

BASF Portsmouth is in a residential area however, it has historically been an industrial site so no issues are anticipated. A strong workforce is available locally.

Table 5.17 summarizes the evaluation. Figure 5.10 shows an aerial photograph of the site.

Table 5.21 Readiness of BASF Portsmouth for different offshore wind activities.

Activity	Conclusion
Blade manufacturing	Dredge to channel or infill to channel Waterside infrastructure Site clearance (warehouses, other buildings)
Generator manufacturing	
Nacelle assembly	
Tower manufacturing	
Foundation manufacturing	
Submarine cable manufacturing	
Construction staging	Dredge to channel or infill to channel Waterside infrastructure Site clearing (warehouses, other buildings)

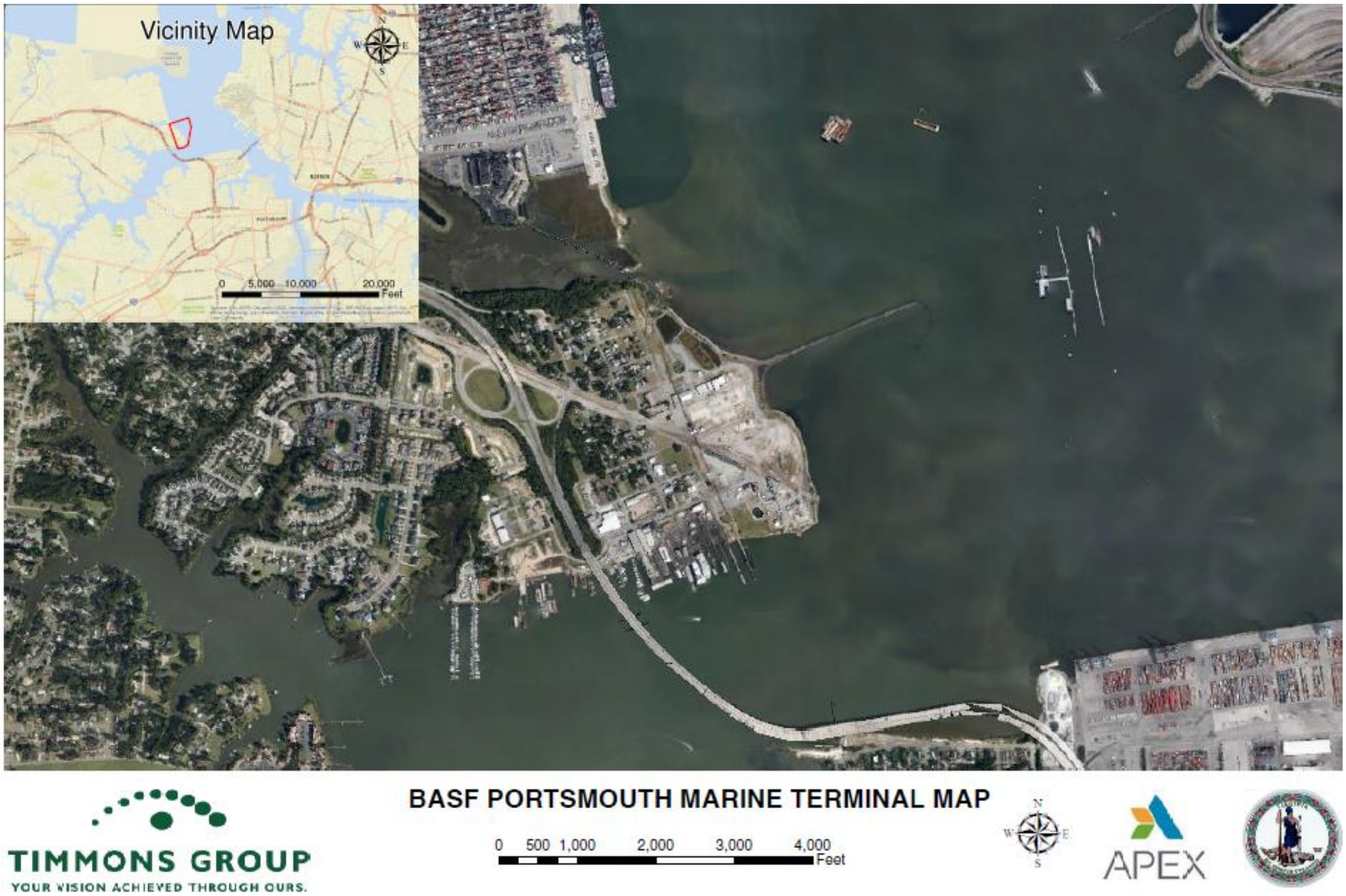

Figure 5.10 An aerial photograph of BASF Portsmouth.

5.11. Commercial shipyard capabilities for substation manufacturing

Background

For substations, it has been assumed that orders would be placed with commercial shipyards (or offshore fabrication yards) and that new, bespoke manufacturing facilities will not be developed. We therefore evaluated the readiness of Virginia's existing commercial shipbuilding sites, each to build two substations per year. We evaluated both conventional and self-installing substations, which have distinctly different requirements.

Conventional substations comprise a foundation (monopole or jacket) and a topside facility housing power electronics and other equipment. The topsides range in mass from about 800 to 2,300t, and are fabricated in a shipyard. The finished topsides are transported to the offshore site and lifted onto their pre-installed offshore foundation using an offshore heavy-lift crane.

For heavier topsides, of mass up to 10,000t, offshore lifting is exceedingly difficult. Instead, a self-installing substation has topsides integrated into a barge with jack up legs. The fully assembled unit is towed to site, where it lowers its legs to the sea bed and jacks up into its final position.

Virginia Shipyards

The Virginia Ship Repair Association has five members with commercial shipbuilding facilities. We evaluated these commercial shipyard facilities for readiness to manufacture conventional and self-installing substations. The five shipyards are:

- BAE Systems Ship Repair
- Colonna's Shipyard
- General Dynamics NASSCO
- Marine Hydraulics International
- Newport News Shipbuilding

All five facilities have the capability to produce conventional substations. Two facilities – BAE Systems and Newport News – have the capability to produce self-installing substations (see Table 5.22). The other shipyards do not have dry docks with sufficient beam.

Table 5.22 Evaluation of commercial shipbuilding capabilities for self-installing and conventional substation manufacturing.

Shipyard parameter	Optimal requirement	BAE Systems	Colonna's Shipyard	General Dynamics NASSCO	Marine Hydraulics International	Newport News Shipbuilding
Number of dry docks	1	2	2	1	0	4
Length (m)	50	1: 290 2: 174	1: 189 2: 70	229	-	1:198 2: 263 3: 217 4: 183
Beam (m)	50	1: 49 2: 31	1: 26 2: 21	37	-	1: 28 2: 35 3: 76 4: 43
Draft (m)	3.5	1: 18.2 2: 18.2	1: 9.1 2: 5.2	-	-	1: 10.1 2: 9.5 3: 10.1 4: 13.1
Evaluation for self-installing substation		Dry dock 1 is suitable, depending on substation design	Insufficient beam	Insufficient beam	No dry dock	Dry dock 3 is suitable Dry dock 4 is suitable, depending on substation design
Evaluation for conventional substation		✓	✓	✓	✓	✓

6. Implementation

This section presents the implementation analysis for the five ports having offshore wind port readiness rating of green or yellow for at least one offshore wind activity. The five ports are:

- Portsmouth Marine Terminal
- Newport News Marine Terminal
- Peck Marine Terminal
- Virginia Renaissance Center, and
- BASF Portsmouth.

Table 6.1 summarizes the implementation costs, time lines and associated construction jobs for upgrading each of the five ports for each of the activities.

Three of the ports -- Portsmouth Marine Terminal, Newport News Marine Terminal and BASF Portsmouth -- were suitable for all seven offshore wind activities. All the ports were suitable for blade manufacturing.

Submarine cable manufacturing has a low requirement for quayside infrastructure and all of the five ports could be used for this activity could be used without significant upgrade.

Portsmouth Marine Terminal, Peck Marine Terminal and BASF Portsmouth have enough space to accommodate multiple activities and these would be particularly suited to turbine assembly, manufacturing and construction staging.

Two of the five of the sites -- Peck Marine Terminal and Virginia Renaissance Center -- have an air draft constraint, which means that these sites cannot be used for jacket foundation manufacturing and construction staging.

BASF Portsmouth has the highest implementation costs, typically five times higher than for the other four ports. This is because of the high cost of dredging to meet requirements for vessel draughts.

Tower manufacturing, foundation manufacturing and construction staging typically have the highest implementation costs. This is typically to upgrade the load-bearing capacity of the quaysides.

Construction staging and potentially foundation manufacturing and are likely to involve the use of jack-up vessels to collect components and transport to the offshore construction site for installation. To do so, jack-up vessels need suitably firm ground conditions beside the quay to raise the hull. Such an assessment requires geotechnical analysis beyond the scope of this evaluation. An early stage in exploring the feasibility of sites for these activities will be undertaking this geotechnical work.

Sections 6.1 to 6.5 present detail for the implementation costs, time lines, and construction jobs at each port, for each activity and for each type of upgrade.

Appendix A provides the assumptions used to derive these estimates.

All construction jobs are reported in FTE-years (full time jobs lasting one year).

Table 6.1 Summary of implementation analysis. The grey cells indicate an activity not evaluated. $$ = implementation cost;

= Time line; = construction jobs

	Portsmouth Marine Terminal	Newport News Marine Terminal	Peck Marine Terminal	Virginia Renaissance Center	BASF Portsmouth
Blade manufacturing	**$$:** $3.0 million-$10.8 million : 27 months : 15.2 FTE-years	**$$:** $2.9 million-$7.9 million : 18 months : 10.6 FTE-years	**$$:** $2.4 million-$8.7million : 7 months : 2.5 FTE-years	**$$:** $1 million-$5 million : 2 months : 1.6 FTE-years	**$$:** $13.3 million-$37.2 million : 3.5 years : 14.5 FTE-years
Generator manufacturing	**$$:** $3.0 million-$10.8 million : 27 months : 15.2 FTE-years	**$$:** $2.9 million-$7.9 million : 18 months : 10.6 FTE-years	**$$:** $1.3 million-$7.2 million : 6 months : 0.7 FTE-years		**$$:** $9.9 million-$32 million : 3 years : 12.8 FTE-years
Nacelle assembly	**$$:** $4.7 million-$16.5 million : 33 months : 25.2 FTE-years	**$$:** $4.5 million-$12.1 million : 22 months : 16.7 FTE-years	**$$:** $2.7 million to $13.8 million : 12 months : 4.2 FTE-years		**$$:** $13.9 million to $37.9 million : 3.5 years : 14.8 FTE-years
Tower manufacturing	**$$:** $5.9 million-$18.9 million : 33 months : 27.4 FTE-years	**$$:** $5.7 million-$14.5 million : 22 months : 18.9 FTE-years	**$$:** $5.1 million to $6.8 million : 4 months : 1.4 FTE-years		**$$:** $13.9 million to $44.7 million : 4 years : 16.3 FTE-years
Foundation manufacturing	**$$:** $5.4 million to $12.5 million : 29 months : 19.2 FTE-years	**$$:** $5.3 million to $13.8 million : 20 months : 17.6 FTE-years			**$$:** $9.3 million to $31.8 million : 2.5 years : 12.4 FTE-years
Submarine cable manufacturing	No upgrades required	No upgrades required	**$$:** $900,000 to $1.3 million : 1 month : 0.5 FTE-years	**$$:** $900,000 to $1.3 million : 1 month : 0.5 FTE-years	**$$:** $12.5 million to $38.9 million : 2.5 years : 14.7 FTE-years
Substation manufacturing	*Substation manufacturing readiness was evaluated at commercial shipyards. No upgrades are required. See Section 5.11*				
Construction staging	**$$:** $7.3 million to $17.3 million : 3 years : 27.3 FTE-years	**$$:** $7.1 million to $14.4 million : 2 years : 21.6 FTE-years			**$$:** $13.5 million to $38.9 million : 3.5 years : 14.7 FTE-years

6.1. Portsmouth Marine Terminal

We estimated implementation costs, time line, and resulting construction jobs for the following activities at Portsmouth Marine Terminal (PMT):

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing
- Foundation manufacturing
- Submarine cable manufacturing, and
- Construction staging.

Waterside infrastructure

PMT has 1,079m of wharf, three berths and is able to handle containers, break-bulk, and roll-on/roll-off cargo. The marginal wharfs at the site typically consist of hollow concrete piles supporting beams and pre-stressed concrete panels, backfilled over and then paved. The site appears to have adequate fenders and bollards based on a visual evaluation.

Ground conditions

Most of PMT was built on reclaimed land containing dredged material from the construction of the Midtown Tunnel. The site topography is generally flat, with a surface treatment in concrete that appears to be in good condition and we noticed no major damage to the surface during the visit.

Vessel access

Navigable access to PMT is through the federal channel with a water depth (MLLW) of 15m. Alongside the berths, the water depth is 13m. The type of soils encountered in the channel has been reported to be sand and silt. The site is about 60nm by sea to the center of the Virginia Wind Energy Area.

Current use

The facility is served by CSX directly and Norfolk Southern via the Norfolk Portsmouth Beltline Railway.

After sitting dormant for nearly three years, the Port of Virginia officially reopened PMT in the second half of 2014. Currently, 60 acres in the northeast corner of the facility are occupied by a joint venture arrangement headed by Skanska Infrastructure Development for construction of a second Midtown Tunnel, scheduled to be complete in 2017. The container yard is in service as an overflow for the traffic at other terminals and the warehouse adjacent to the Virginia International Terminals operations building is also currently occupied.

Road and rail access

The site has good road access with the proximity to Interstate I-264 and I-664 and State Route 164.

The site extends up to 450m inland.

Implementation Summary

Blade and generator manufacturing require improved quay strength.

Nacelle assembly and tower manufacturing require improved quay strength and improved ground strength for crane paths.

Submarine cable manufacturing does not require any upgrades.

Foundation manufacturing and construction staging require improved quay strength and improved ground strength for the storage areas.

Table 6.2 Implementation summary for Portsmouth Marine Terminal.

Activity	Cost to complete	Time to complete	Jobs (FTE-years)
Blade manufacturing	$3.0 million to $10.8 million	27 months	15.2
Generator manufacturing	$3.0 million to $10.8 million	27 months	15.2
Nacelle assembly	$4.7 million to $16.5 million	33 months	25.2
Tower manufacturing	$5.9 million to $18.9 million	33 months	27.4
Foundation manufacturing	$5.4 million to $12.5 million	29 months	19.2
Submarine cable manufacturing	No upgrades required		
Construction staging	$7.3 million to $17.3 million	3 years	27.3

Table 6.3 Implementation estimates for blade manufacturing at Portsmouth Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	Port characteristic	Units	Required	Actual	Cost	Time	Jobs
Water access	Horizontal clearance	m	25.0	228	✓	✓	✓
	Air draft	m	20	N/A	✓	✓	✓
	Vessel draft	m	9.0	12.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	222,500 (55)	1,161,500 (287)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	200	1079	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	5	4.1	$3.0 million - $10.8 million	27 months	15.2
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,000	22,400			
On-site storage	Open air	m^2	125,000	748,668	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	Yes	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

BVGassociates

Table 6.4 Implementation estimates for generator manufacturing at Portsmouth Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	35.0	228	✓	✓	✓
	Air draft	m	15	N/A	✓	✓	✓
	Vessel draft	m	5.0	12.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	70,000 (17.3)	1,161,500 (287)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	200	1079	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	10	4.1	$3.0 million - $10.8 million	27 months	15.2
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,000	22,400			
On-site storage	Open air	m^2	0	748,668	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.5 Implementation estimates for nacelle assembly at Portsmouth Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	Port characteristic	Units	Required	Actual	Cost	Time	Jobs
Water access	Horizontal clearance	m	25.0	228	✓	✓	✓
	Air draft	m	20	N/A	✓	✓	✓
	Vessel draft	m	9.0	12.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	100,000 (24.7)	1,161,500 (287)	✓	✓	✓
	Ground bearing pressure	t/m^2	10	varies	\$100,000-\$400,000	1 month	0.2
	Round-the-clock operation	Yes or No	Yes	Yes	✓	✓	✓
Quay	Length	m	300	1079	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	20	4.1	\$4.5 million - \$16.1 million	33 months	25.2
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,500	22,400			
On-site storage	Open air	m^2	10,500	748,668	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.6 Implementation estimates for tower manufacturing at Portsmouth Marine Terminal. The ticks indicate that no upgrade is necessary.

Category	Port characteristic	Units	Required	Actual	Implementation		
					Cost	Time	Jobs
Water access	Horizontal clearance	m	25.0	228	✓	✓	✓
	Air draft	m	20	N/A	✓	✓	✓
	Vessel draft	m	9.0	12.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	150,000 (37.1)	1,161,500 (287)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	varies	$1.4 million to $2.8 million	1 month	0.8
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	300	1,100	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	10	4.1	$4.5 million-$16.1 million	33 months	26.6
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,500	22,000			
On-site storage	Open air	m^2	75,000	750,000	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	Yes	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.7 Implementation estimates for foundation manufacturing and staging at Portsmouth Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	35.0	228	✓	✓	✓
	Air draft	m	85	N/A	✓	✓	✓
	Vessel draft	m	5.0	12.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	220,000 (55)	1,161,500 (287)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	varies	\$2.2 million - \$4.5 million	2 months	1.2
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	M	125	1,079	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	20	4.1	\$3.2 million- \$8.0 million	29 months	19.2
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,250	22,400			
On-site storage	Open air	m^2	120,000	750,000	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.8 Implementation estimates for cable manufacturing at Portsmouth Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	27.5	228	✓	✓	✓
	Air draft	m	30	N/A	✓	✓	✓
	Vessel draft	m	5.8	12.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	90,000 (20)	1,161,500 (287)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	varies	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	125	1,100	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	N/A	4.1	✓	✓	✓
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	N/A	20,000	✓	✓	✓
On-site storage	Storage space - open air	m^2	0	750,000	✓	✓	✓
	Storage space - enclosed area	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.9 Implementation estimates for construction staging at Portsmouth Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	Port characteristic	Units	Required	Actual	Cost	Time	Jobs
Water access	Horizontal clearance	m	110	230	✓	✓	✓
	Air draft	m	130	N/A	✓	✓	✓
	Vessel draft	m	8.0	12.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	50,000 (12)	1,161,500 (287)	✓	✓	✓
	Ground bearing pressure	t/m^2	10	varies	\$2.2 million - \$4.5 million	2 months	1.2
	Round-the-clock operation	Yes or No	Yes	Yes	✓	✓	✓
Quay	Length	m	200	1079	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	Yes	unknown	See discussion in Section 6		
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	25	4.1	\$5.1 million - \$12.8 million	36 months	27.3
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	2,000	22,400	✓	✓	✓
On-site storage	Storage space - open air	m^2	80,000	750,000	✓	✓	✓
	Storage space - enclosed area	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

6.2. Newport News Marine Terminal

We estimated implementation costs, time line, and resulting construction jobs for the following activities at Newport News Marine Terminal (NNMT):

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing
- Submarine cable manufacturing, and
- Construction staging.

Waterside infrastructure

NNMT piers B and C have length 180m and 280m, respectively, and are able to handle containers, break-bulk, and roll-on/roll-off cargo. The piers are built on concrete pillars.

Ground conditions

The topography of the site is generally flat. Surface treatments of concrete or asphalt that appear to be in good condition and no major damage to the surface observed during the site visit.

Vessel access

Navigable access to NNMT is through the federal channel with a water depth (MLLW) of 15m. Alongside piers B and C the water depth is 9m and 7.5m, respectively.

Current use

The site currently has multiple users, mainly for break bulk cargo (including car import) but there is still space available.

The property adjacent to the NNMT is the Dominion Terminal, a coal shipping and ground storage facility. The facility has a coal dust control system (wet suppression) in place to mitigate fugitive coal dust emissions. A US navy facility is on the other side of NNMT.

Road and rail access

The site has good road access with the proximity to Interstate-664 and State Route 17.

Implementation Summary

Blade manufacturing and generator require improved quay strength.

Nacelle assembly and tower manufacturing require improved quay strength and improved ground strength for crane paths.

Submarine cable manufacturing does not require any upgrades.

Foundation manufacturing and construction staging require improved quay strength and improved ground strength for the storage areas.

Table 6.10 Implementation summary for Newport News Marine Terminal.

Activity	Cost to complete	Time to complete	Jobs (FTE-years)
Blade manufacturing	$2.9 million to $7.9 million	18months	10.6
Generator manufacturing	$2.9 million to $7.9 million	18 months	10.6
Nacelle assembly	$4.5 million to $12.1 million	22 months	16.7
Tower manufacturing	$5.7 million to $14.5 million	22 months	18.9
Foundation manufacturing	$5.3 million to $13.8 million	20 months	17.6
Submarine cable manufacturing	No upgrades required		
Construction staging	$7.1 million to $14.4 million	2 years	21.6

Table 6.11 Implementation estimates for blade manufacturing at Newport News Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	25.0	244	✓	✓	✓
	Air draft	m	20	N/A	✓	✓	✓
	Vessel draft	m	9.0	14.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	222,500 (55)	668,000 (165)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	varies	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	200	2,400	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	5	4.1	$2.9 million - $7.9 million	18 months	10.6
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,000	38,000			
On-site storage	Open air	m^2	125,000	240,000	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	Yes	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.12 Implementation estimates for generator manufacturing at Newport News Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	Port characteristic	Units	Required	Actual	Cost	Time	Jobs
Water access	Horizontal clearance	m	35.0	244	✓	✓	✓
	Air draft	m	15	N/A	✓	✓	✓
	Vessel draft	m	5.0	14.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	70,000 (17.3)	668,000 (165)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	200	2,400	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	10	4.1	$2.9 million-$7.9 million	18 months	10.6
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,000	38,000			
On-site storage	Open air	m^2	0	240,000	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.13 Implementation estimates for nacelle assembly at Newport News Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	25.0	244	✓	✓	✓
	Air draft	m	20	N/A	✓	✓	✓
	Vessel draft	m	9.0	14.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	100,000 (24.7)	668,000 (165)	✓	✓	✓
	Ground bearing pressure	t/m^2	10	12.2	\$200,000-\$400,000	1 month	0.2
	Round-the-clock operation	Yes or No	Yes	Yes	✓	✓	✓
Quay	Length	m	300	2,400	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	20	4.1	\$4.3 million-\$11.7 million	22 months	16.5
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,500	38,000			
On-site storage	Open air	m^2	10,500	240,000	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.14 Implementation estimates for tower manufacturing at Newport News Marine Terminal. The ticks indicate that no upgrade is necessary.

Category	Port characteristic	Units	Required	Actual	Implementation		
					Cost	Time	Jobs
Water access	Horizontal clearance	m	25.0	244	✓	✓	✓
	Air draft	m	20	N/A	✓	✓	✓
	Vessel draft	m	9.0	14.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	150,000 (37.1)	668,000 (165)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	12.2	\$1.4 million - \$2.8 million	2 month	0.8
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	300	2,400	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	10	4.1	\$4.3 million-\$11.7 million	22 months	18.1
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,500	38,000			
On-site storage	Open air	m^2	75,000	240,000	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	Yes	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.15 Implementation estimates for foundation manufacturing and staging at Newport News Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	Port characteristic	Units	Required	Actual	Cost	Time	Jobs
Water access	Horizontal clearance	m	35.0	244	✓	✓	✓
	Air draft	m	85	N/A	✓	✓	✓
	Vessel draft	m	5.0	14.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	220,000 (55)	668,000 (165)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	12.2	\$2.2 million - \$4.5 million	2 months	1.2
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	M	125	2,400	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	20	4.1	\$3.1 million-\$9.3 million	20 months	16.4
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,250	38,000			
On-site storage	Open air	m^2	120,000	240,000	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.16 Implementation estimates for cable manufacturing at Newport News Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	27.5	244	✓	✓	✓
	Air draft	m	30	N/A	✓	✓	✓
	Vessel draft	m	5.8	14.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	90,000 (20)	668,000 (165)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	125	2,400	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	N/A	4.1	✓	✓	✓
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	N/A	38,000	✓	✓	✓
On-site storage	Storage space - open air	m^2	0	240,000	✓	✓	✓
	Storage space - enclosed area	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.17 Implementation estimates for construction staging at Newport News Marine Terminal. The ticks indicate that no upgrade is necessary.

Category	Port characteristic	Units	Required	Actual	Implementation		
					Cost	Time	Jobs
Water access	Horizontal clearance	m	110	244	✓	✓	✓
	Air draft	m	130	N/A	✓	✓	✓
	Vessel draft	m	8.0	14.3	✓	✓	✓
Waterfront site	Total area	m^2 (acres)	50,000 (12)	668,000 (165)	✓	✓	✓
	Ground bearing pressure	t/m^2	10	12.2	\$2.2 million - \$4.5 million	2 months	1.2
	Round-the-clock operation	Yes or No	Yes	Yes	✓	✓	✓
Quay	Length	m	200	2,400	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	Yes	No	See discussion in Section 6		
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	25	4.1	\$4.9 million - \$9.9 million	24 months	20.4
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	2,000	38,000	✓	✓	✓
On-site storage	Storage space - open air	m^2	80,000	240,000	✓	✓	✓
	Storage space - enclosed area	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

6.3. Peck Marine Terminal

We estimated implementation costs, time line, and resulting construction jobs for the following activities at Peck Marine Terminal (Peck):

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing, and
- Submarine cable manufacturing.

Waterside infrastructure

Peck has a 126m pier built in 2007/2008. The relatively narrow pier is built on concrete pillars. Our visual inspection indicated the pier is in good condition. It is reported to have a reinforced area with 200t capacity. Sheet pile walls have been installed near the pier to consolidate and retain the earth but look in need of repair.

Ground conditions

The site occupies has cleared, level ground that is largely laid with 0.5m thick reinforced concrete beams.

There are several office buildings and warehouse totalling 6,000m^2.

Vessel access

Navigable access to Peck is through the federal channel with a water depth (MLLW) of 14m. The water depth (MLLW) alongside the pier is 8m.

Current use

Peck is not currently used. The site was previously owned by Texaco, who used the site as a petroleum refining facility. Empty fuel storage tanks remain on site.

Road and rail access

The facility is served by rail by CSX and Norfolk Southern. The site has good road access with the proximity to Interstate I-464 and I-64.

The entrance road to the site has an overhead obstruction in the form of overhead pipelines, limiting the height for the vehicles access to 4.2m (13'9").

Implementation Summary

Blade manufacturing and generator require improved quay strength.

Nacelle assembly and tower manufacturing require improved quay strength and improved ground strength for crane paths.

Submarine cable manufacturing does not require any upgrades.

Foundation manufacturing and construction staging require improved quay strength and improved ground strength for the storage areas.

Table 6.18 Implementation summary for Peck Marine Terminal.

Activity	Cost to complete	Time to complete	Jobs (FTE-years)
Blade manufacturing	$2.4 million to 8.7million	7 months	2.5
Generator manufacturing	$1.3 million to $7.2 million	6 months	0.7
Nacelle assembly	$2.7 million to $13.8 million	12 months	4.2
Tower manufacturing	$5.1 million to $6.8 million	4 months	1.4
Submarine cable manufacturing	$900,000 to $1.3 million	1 months	0.5

Table 6.19 Implementation estimates for blade manufacturing at Peck Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	25.0	114	✓	✓	✓
	Air draft	m	20	44.2	✓	✓	✓
	Vessel draft	m	9.0	8.0	\$1.0 million-\$1.5 million	1 month	0.5
Waterfront site	Total area	m^2 (acres)	222,500 (55)	253,300 (62.6)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	200	125	\$1.2 million-\$7.0 million	5 months	1.9
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	5	4.1	\$200,000	1 month	0.1
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,000	6,250			
On-site storage	Open air	m^2	125,000	55,700	✓	✓	✓
	Enclosed	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	Yes	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.20 Implementation estimates for generator manufacturing at Peck Marine Terminal. The ticks indicate that no upgrade is necessary.

Category	Port characteristic	Units	Required	Actual	Implementation		
					Cost	Time	Jobs
Water access	Horizontal clearance	m	35.0	114	✓	✓	✓
	Air draft	m	15	44.2	✓	✓	✓
	Vessel draft	m	5.0	8.0	up to $100,000	1 week	0.1
Waterfront site	Total area	m^2 (acres)	70,000 (17.3)	253,300 (62.6)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	200	125	$1.2 million-$7.0 million	5 months	0.5
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	10	4.1	$100,000-$200,000	1 month	0.1
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,000	6,250			
On-site storage	Open air	m^2	0	55,700	✓	✓	✓
	Enclosed	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.21 Implementation estimates for nacelle assembly at Peck Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	Port characteristic	Units	Required	Actual	Cost	Time	Jobs
Water access	Horizontal clearance	m	25.0	114	✓	✓	✓
	Air draft	m	20	44.2	✓	✓	✓
	Vessel draft	m	9.0	8.0	\$1.0 million-\$1.5 million	1 month	0.5
Waterfront site	Total area	m^2 (acres)	100,000 (24.7)	253,300 (62.6)	✓	✓	✓
	Ground bearing pressure	t/m^2	10	12.2	\$200,000-\$400,000	2 months	0.3
	Round-the-clock operation	Yes or No	Yes	Yes	✓	✓	✓
Quay	Length	m	300	125	\$1.3 million-\$11.5 million	8 months	3.2
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	20	4.1	\$200,000-\$400,000	1 month	0.2
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,500	6,250			
On-site storage	Open air	m^2	10,500	55,700	✓	✓	✓
	Enclosed	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.22 Implementation estimates for tower manufacturing at Peck Marine Terminal. The ticks indicate that no upgrade is necessary.

Category	Port characteristic	Units	Required	Actual	Implementation: Cost	Time	Jobs
Water access	Horizontal clearance	m	25.0	114	✓	✓	✓
	Air draft	m	20	44.2	✓	✓	✓
	Vessel draft	m	9.0	8.0	\$1.0 million-\$1.5 million	1 month	0.5
Waterfront site	Total area	m^2 (acres)	150,000 (37.1)	253,300 (62.6)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	300	125	\$3.9 million-\$4.7 million	2 months	0.7
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	10	4.1	\$200,000-\$400,000	1 month	0.2
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,500	6,250			
On-site storage	Open air	m^2	75,000	55,700	✓	✓	✓
	Enclosed	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	Yes	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓

Table 6.23 Implementation estimates for cable manufacturing at Peck Marine Terminal. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	27.5	114	✓	✓	✓
	Air draft	m	30	44.2	✓	✓	✓
	Vessel draft	m	5.8	8.0	$900,000-$1.3 million	1 month	0.5
Waterfront site	Total area	m^2 (acres)	90,000 (20)	253,300 (62.6)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	125	125	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	N/A	4.1	✓	✓	✓
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	N/A	6,250	✓	✓	✓
On-site storage	Storage space - open air	m^2	0	55,700	✓	✓	✓
	Storage space - enclosed area	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	114	✓	✓	✓
	Gas utility connection	Yes or No	Yes	44.2	✓	✓	✓

6.4. Virginia Renaissance Center

We estimated implementation costs, time line, and resulting construction jobs for the following activities at Virginia Renaissance Venter (VRC):

- Blade manufacturing and
- Submarine cable manufacturing.

Waterside infrastructure

VRC has a 137m pier.

Ground conditions

The buildings from the former Ford Plant have been razed and only the concrete slabs and asphalt parking remain.

Vessel access

Between VRC and the open sea, vessels dimensions and movement would be restricted by a series of bridges: the Berkley Bridge, the Norfolk Southern railway bridge and the Campostella bridge.

Current use

VRC is not currently used. The site was previously a Ford truck plant. Concrete slabs from the truck plant remain on site.

Road and rail access

VRC has good highway access, located just off Route 407 with quick access to interstate highways 264 and 464.

VRC has a Norfolk Southern Rail connection.

Implementation Summary

Blade manufacturing requires improved quay strength.

Submarine cable manufacturing requires dredging.

Table 6.24 Implementation summary for Peck Marine Terminal.

Activity	Cost to complete	Time to complete	Jobs (FTE-years)
Blade manufacturing	$1 million to $1.5 million	2 months	1.6
Submarine cable manufacturing	$900,000 to $1.3 million	1 month	0.5

Table 6.25 Implementation estimates for blade manufacturing at Virginia Renaissance Center. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	25.0	91.4	✓	✓	✓
	Air draft	m	20	19.8	✓	✓	✓
	Vessel draft	m	9.0	2.8	\$900,000-\$1.3 million	1 month	0.5
Waterfront site	Total area	m^2 (acres)	222,500 (55)	280,000 (70)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	200	134	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	5	4.1	\$100,000-\$200,000	1 month	0.1
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,000	6,700			
On-site storage	Open air	m^2	125,000	50,000	✓	✓	✓
	Enclosed	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	Yes	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.26 Implementation estimates for cable manufacturing at Virginia Renaissance Center. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	27.5	91.4	✓	✓	✓
	Air draft	m	30	19.8	*Barge access only*		
	Vessel draft	m	5.8	2.8	$900,000-$1.3 million	1 month	0.5
Waterfront site	Total area	m^2 (acres)	90,000 (20)	280,000 (70)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	125	134	✓	✓	✓
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	N/A	4.1	✓	✓	✓
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	N/A	6,700			
On-site storage	Storage space - open air	m^2	0	50,000	✓	✓	✓
	Storage space - enclosed area	m^2	0	0	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

6.5. BASF Portsmouth

We estimated implementation costs, time line, and resulting construction jobs for the following activities at BASF Portsmouth (BASF-P):

- Blade manufacturing
- Generator manufacturing
- Nacelle assembly
- Tower manufacturing
- Submarine cable manufacturing, and
- Construction staging.

Waterside infrastructure

BASF-P is not a contiguous site. This analysis considers the northern section of the site, which has no accessible waterside infrastructure.

Ground conditions

The site is flat and includes remaining s from previous BASF activities, including concrete slabs available for a warehouse. Several of the office buildings that were part of the site have been sold and are no longer considered part of the site.

The property owner is pursuing an environmental closure report with the Virginia Department of Environmental Quality, however at the time of the study, it was not completed.

Vessel access

Navigable access to BASF-P is through the federal channel with a water depth of 15m (MLLW). Between the federal channel and the site the water depth is only about 1m.

Current use

BASF-P is not currently used. It was previously a BASF site with offices and manufacturing..

Road and rail access

BASF-P is served by both CSX directly and Norfolk Southern via the Commonwealth railroad. The site has also good road access with the proximity to State Route 164.

Implementation Summary

Any offshore wind activities would require major infrastructure improvements.

Blade, generator, and cable manufacturing require dredging and a new pier.

Nacelle assembly, tower manufacturing, and construction staging require dredging, a new pier, and ground strengthening.

Table 6.27 Implementation summary for BASF Portsmouth.

Activity	Cost to complete	Time to complete	Jobs (FTE-years)
Blade manufacturing	$13.3 million to $37.2 million	3.5 years	14.5
Generator manufacturing	$9.9 million to $32 million	3 years	12.8
Nacelle assembly	$13.5 million to $37.9 million	3.5 years	14.8
Tower manufacturing	$13.9 million to $44.7 million	4 years	16.3
Foundation manufacturing	$9.3 million to $31.8 million	2.5 years	12.4
Submarine cable manufacturing	$7.9 million to $29.9 million	2.5 years	12.1
Construction staging	$12.5 million to $38.9 million	3.5 years	14.7

Table 6.28 Implementation estimates for blade manufacturing at BASF Portsmouth. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	25.0	228	✓	✓	✓
	Air draft	m	20	N/A	✓	✓	✓
	Vessel draft	m	9.0	4.2	\$6.3 million - \$9.7 million	7 months	3.3
Waterfront site	Total area	m^2 (acres)	222,500 (55)	178,000 (44)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	200	0	\$7.0 million - \$27.5 million	2 .5 years	11.2
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	5	4.1	Included with quay length extension		
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,000	7,000			
On-site storage	Open air	m^2	125,000	51,000	✓	✓	✓
	Enclosed	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	Yes	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.29 Implementation estimates for generator manufacturing at BASF Portsmouth. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	Port characteristic	Units	Required	Actual	Cost	Time	Jobs
Water access	Horizontal clearance	m	35.0	228	✓	✓	✓
	Air draft	m	15	N/A	✓	✓	✓
	Vessel draft	m	5.0	4.2	\$2.9 million-\$4.5 million	3 months	1.6
Waterfront site	Total area	m^2 (acres)	70,000 (17.3)	178,000 (44)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	200	0	\$7.0 million - \$27.5 million	2 .5 years	11.2
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	10	4.1	Included with quay length extension		
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,000	7,000			
On-site storage	Open air	m^2	0	51,000	✓	✓	✓
	Enclosed	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.30 Implementation estimates for nacelle assembly at BASF Portsmouth. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	25.0	228	✓	✓	✓
	Air draft	m	20	N/A	✓	✓	✓
	Vessel draft	m	9.0	4.2	\$6.5 million-\$10.0 million	7 months	3.4
Waterfront site	Total area	m^2 (acres)	100,000 (24.7)	178,000 (44)	✓	✓	✓
	Ground bearing pressure	t/m^2	10	12.2	up to \$400,000	1 month	0.2
	Round-the-clock operation	Yes or No	Yes	Yes	✓	✓	✓
Quay	Length	m	300	0	\$7.0 million - \$27.5 million	2 .5 years	11.2
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	20	4.1	Included with quay length extension		
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,500	7,000			
On-site storage	Open air	m^2	10,500	51,000	✓	✓	✓
	Enclosed	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.31 Implementation estimates for tower manufacturing at BASF Portsmouth. The ticks indicate that no upgrade is necessary.

Category	Port characteristic	Units	Required	Actual	Implementation		
					Cost	Time	Jobs
Water access	Horizontal clearance	m	25.0	228	✓	✓	✓
	Air draft	m	20	N/A	✓	✓	✓
	Vessel draft	m	9.0	4.2	$6.5 million-$10.0 million	7 months	3.4
Waterfront site	Total area	m^2 (acres)	150,000 (37.1)	178,000 (44)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	12.2	up to $3.0 million	1.5 months	0.6
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	300	0	$7.4 million - $31.7 million	3 year	12.3
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	10	4.1	Included with quay length extension		
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,500	7,000			
On-site storage	Open air	m^2	75,000	51,000	✓	✓	✓
	Enclosed	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	Yes	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.32 Implementation estimates for foundation manufacturing and staging at BASF Portsmouth. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	35.0	228	✓	✓	✓
	Air draft	m	85	N/A	✓	✓	✓
	Vessel draft	m	5.0	4.2	\$2.9 million - \$4.5 million	3 months	1.6
Waterfront site	Total area	m^2 (acres)	220,000 (55)	178,000 (44)	✓	✓	✓
	Ground bearing pressure	t/m^2	5	12.2	\$2.1 million - \$3.0 million	2 months	0.6
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	M	125	0	\$4.3 million - \$24.3 million	2 years	10.2
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	20	4.1	Included in quay length extension		
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	1,250	7,000			
On-site storage	Open air	m^2	120,000	51,000	✓	✓	✓
	Enclosed	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.33 Implementation estimates for cable manufacturing at BASF Portsmouth. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	27.5	228	✓	✓	✓
	Air draft	m	30	N/A	✓	✓	✓
	Vessel draft	m	5.8	4.2	\$3.6 million - \$5.6 million	4 months	1.9
Waterfront site	Total area	m^2 (acres)	90,000 (20)	178,000 (44)	✓	✓	✓
	Ground bearing pressure	t/m^2	2	12.2	✓	✓	✓
	Round-the-clock operation	Yes or No	No	Yes	✓	✓	✓
Quay	Length	m	125	0	\$4.3 million - \$24.3 million	2 years	10.2
	Accommodate jack-up vessels	Yes or No	No	No	✓	✓	✓
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	N/A	4.1	✓	✓	✓
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	N/A	7,000	✓	✓	✓
On-site storage	Storage space - open air	m^2	0	51,000	✓	✓	✓
	Storage space - enclosed area	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Table 6.34 Implementation estimates for construction staging at BASF Portsmouth. The ticks indicate that no upgrade is necessary.

					Implementation		
Category	**Port characteristic**	**Units**	**Required**	**Actual**	**Cost**	**Time**	**Jobs**
Water access	Horizontal clearance	m	110	228	✓	✓	✓
	Air draft	m	130	N/A	✓	✓	✓
	Vessel draft	m	8.0	4.2	\$5.5 million - \$8.4 million	6 months	2.9
Waterfront site	Total area	m^2 (acres)	50,000 (12)	178,000 (44)	✓	✓	✓
	Ground bearing pressure	t/m^2	10	12.2	up to \$3.0 million	2 months	0.6
	Round-the-clock operation	Yes or No	Yes	Yes	✓	✓	✓
Quay	Length	m	200	0	\$7.0 million - \$27.5 million	2.5 years	11.2
	Accommodate jack-up vessels	Yes or No	Yes	No	See discussion in Section 6		
	Quayside ground strength (crane footprint and lay-down areas)	t/m^2	25	4.1	Included in quay length extension		
	Reinforced quayside area (crane footprint and lay-down areas)	m^2	2,000	7,000			
On-site storage	Storage space - open air	m^2	80,000	51,000	✓	✓	✓
	Storage space - enclosed area	m^2	0	365	✓	✓	✓
Road access	Standard truck	Yes or No	Yes	Yes	✓	✓	✓
	Oversize truck	Yes or No	No	Yes	✓	✓	✓
Rail access	Rail access	Yes or No	No	Yes	✓	✓	✓
Utilities	Electrical service - rating	Yes or No	Yes	Yes	✓	✓	✓
	Process water consumption	Yes or No	Yes	Yes	✓	✓	✓
	Gas utility connection	Yes or No	Yes	Yes	✓	✓	✓

Appendix A: Estimates used for implementation analysis

This appendix provides further details on the calculation of data in the tables in Section 6.

Overview

We used standard engineering assumptions and methods to determine material quantities and costs. When necessary we made assumptions about existing conditions, which are noted below.

The largest unknown is subsurface geotechnical data. For most of the sites, the existing information available was limited or non-existent. Ground bearing capacity is a critical factor for offshore wind facilities, so prior to any final evaluation of any one facility, a geotechnical investigation should be conducted to reduce the uncertainty in the estimates reported here.

The estimates for implementation time lines and associated construction jobs include the effort for the engineering and permitting workers.

Repair costs for existing port infrastructure

Portsmouth Marine Terminal requires extensive repairs to its existing waterfront infrastructure. Collins Engineers performed an evaluation of condition in 2013. For the western section of the quay, total repair costs were estimated at $1.7 million. These upgrades were necessary for their existing operations, so they have not been factored into any upgrades to support the offshore wind industry; however, there is the possibility the efforts would complement each other and lead to a reduction in overall costs.

Collins Engineers also evaluated the quayside infrastructure for Newport News Marine Terminal. Total repair costs to the sections of the quay needed for proposed development were estimated at $600,000. As above, these upgrades were necessary for their existing operations, so again they have not been factored into any upgrades to support the offshore wind industry; however, it is possible the efforts would complement each other and lead to a reduction in overall costs.

Ground bearing capacity

At Portsmouth Marine Terminal, marginal wharf areas and numbers of piles per wharf were obtained from Collins Engineers' 2013 condition evaluation of existing wharf structures. Five regions of the wharf were analyzed separately. This information was used by Apex to calculate an estimated design bearing capacity for the concrete pier.

The minimum bearing capacity occurred at the second wharf, which had 102 piles, each of 120 ton capacity supporting a 2,150 m^2 concrete deck. A 0.91 conversion factor from ton to metric tonne and a 1.25 factor of safety are included below:

$$\text{Minimum Design Bearing Capacity} = \frac{(0.91)(102)(120)}{(2{,}150)(1.25)}$$
$$= 4.1\ \mathrm{t/m^2}$$

This is the available pile capacity based on the concrete pile alone. Since each marginal wharf structure includes concrete pile cap beams, a prestressed concrete deck, earthen fill and an asphalt cover, there is additional dead load that reduces the available pile bearing strength. Therefore based on the profile of marginal wharf 2 at PMT, we estimated an available pile capacity of 1.47 $\mathrm{t/m^2}$

According to the Das *Pringciples of Geotehcnical Engingeering* textbook, sand and gravel fill provide 3000 psf (pounds per square foot) of bearing capacity while silty sand provides 2000 psf. For estimation purposes, an average of 2500 psf was used. Converting 2500 psf to metric units yielded an estimated ground bearing strength of 12.2 t/m^2 for the upland sections of the waterfront site. Soil characteristics can vary widely, so for cost estimating, if the actual conditions were greater than the optimal conditions, a bearing capacity improvement was still calculated because of the variability of the soil characteristics.

These values for quayside and upland ground bearing strength are suitable for cost estimating purposes but should not be used for design purposes. A geotechnical investigation is recommended prior to the start of any site improvements.

For improvement of upland ground strength, it is assumed that cross-laminated timber (CLT) mats or dunnage would only be laid down on a small percentage of the total on-site storage area as it will be arranged with "crane lanes." For estimation of this percentage, 8m reinforced roadways were assumed to surround 150m long, 70m wide storage areas. Within each storage area, four 150m long, 4m wide reinforced section would be spaced evenly between unreinforced areas. Based on these assumptions and subsequent calculations, it was determined that approximately 15% of total on-site storage area required reinforcement with CLT mats or dunnage, while the remaining 85% could remain unreinforced.

Unlike upland ground strengthening, it was assumed that quayside reinforcement would require 100% area coverage. For the marginal wharf and pier structures, CLTs can distribute the load over a wider footprint, however the "pile caps" appear to be too far apart to spread the load to the adjacent piles. Given the stiffness of the piles and the elasticity of the timber, a heavy load such as used in offshore wind would create an incompatability to transfer the loads. In order to be able to effectively transfer the load, the upgrade would need to be made with a material with similar stiffness properties, such as a steel girder, or to raze and rebuild the wharf structure to better handle the loads.

The bulkheads at PMT and NNMT are sheet pile supported structures. As an upgrade to the bearing strength of the bulkheads, we have assumed soil nails with threaded rods were sufficient to provide additional strength under the heavy loading conditions of moving OSW components.

Ground strength improvements

CLT Materials

Cross laminated timber (CLT) mats were chosen as one ground strengthening alternative after researching its prior uses and speaking with a few manufacturers. CLT mats were rated at 70,000 psf of down pressure according to the Rig Mats of America company brochure.

The manufacturer estimated costs at $4,300 per 8’x40’ section.

RS Means Online was used to obtain crew estimates and daily output projections. Crew and equipment costs were then factored into the total cost of CLT.

CLT was determined to have a total unit cost of $153/m^2 per single crew.

Dunnage materials

Dunnage costs were calculated using RS Means online. The estimated total unit cost was calculated to be $68.70/m^2 per single crew. A strength rating for dunnage was not readily available.

Cost and spacing assumptions for pier and quayside improvements

Most of the quayside costs were estimated using cost figures from current/recent marine construction projects that involve large scale pier construction. When this information was unavailable, data from RS Means was used.

- Cost per cofferdam cell unit (1 major cell, 1 minor cell): $651,000
- Cofferdam unit spacing: 25m
- Cost per pipe pile: $12,185
- Pipe pile spacing: 3.2m
- Cost per socketed pile: $69,260
- Socketed pile spacing: 3.5m
- Cost per pile cap: $2,700
- Cost per Bollard: $19,600
- Bollard spacing: 14m
- Cost per fender: $17,300
- Fender spacing: 14m
- Cost per dolphin, with 6 x 18m long wooden, treated piles priced at $158.50 per pile per meter: (158.50)(6)(18) = $17,000/dolphin
- Cost of structural backfill, using RS means unit values of $32.05/m^3 for backfill furnishing and delivery, $2.56/m^3 for backfill installation including crew and equipment, and $1.00/m^3 for compaction of the backfill: $35.61/m^3

Additional pier and quayside improvement assumptions

Estimate for Peck Marine Terminal’s needed backfill for quayside improvements assumed a 15m average width between the pier and the existing shoreline, a 4m average water depth behind the pier with length dependent on the needed quay length of the manufacturing component being analyzed.

BASF Portsmouth proposed pier length was chosen to be 550m, with a width of 70m for the higher cost option that used cofferdam cells and structural backfill, or width of 15m for the lower cost option that used only concrete piles to support the proposed pier.

For the higher cost option, the estimate for BASF Portsmouth’s needed backfill for quayside improvements used a 50m width after accounting for the space used by the cofferdam cells, an average depth of fill of 4 m and length of 550m. Total fill needed was estimated to be 110,000m^3.

Cultec materials for drainage upgrades

Cultec plastic drainage chambers were used to estimate the cost of filling the storm water ponds that were present at Peck and BASF Portsmouth Marine Terminals. Installation of Cultec was assumed to include 12” of structural backfill below the Cultec chambers as well as 10” of structural backfill above. Based on the size of the storm water ponds, it was estimated that an additional foot of structural backfill would be needed to level the ground after filling the ponds.

Cultec unit cost: $275 per 8’x3’ section.

In addition, a cost of backfill estimate of $35.61/m^3 (*see Cost and Spacing Assumptions for Pier and Quayside Improvements*) including crew and equipment costs were used to estimate a total Cultec unit price.

Cultec was determined to have a total unit cost of $155/m^2.

Navigational access

Dredging volumes were calculated using NOAA charts for estimating average depths.

Peck Marine Terminal total dredge footprint: 24,000 m^2. The majority of this area is approximately 8 m deep, however a 40 m by 50 m section in front of the pier has an average depth of 4 m. Since some OSW manufacturing components required 9 m water depth, the following calculation estimated needed dredge volume:

$$\begin{aligned} &Total\ Dredge\ Volume \\ &= (9-8)\big(24{,}000 \\ &- (40)(50)\big) \\ &+ (9-4)(40)(50) \\ &= 32{,}000\ m^3 \end{aligned}$$

BASF Portsmouth had variable needed dredge volume depending on the water depth required for manufacturing of each component. The width of the dredge channel is 40 m. The average depth of the berthing zone was 0.3 m, while the average depth of the 430 m long, 40 m wide approach channel is 2.2 m. The total area of dredge footprint ranges from 24,200 m^2 to 31,200 m^2 depending on the manufacturing component being considered.

Timeline and labor assumptions

Timelines were estimated based on a single crew's typical work output

- Cultec: 3 crew, 615 m^2/day
- CLT: 2 crew, 50 m^2/day (100 m^2/day if several crews are working together on a larger-scale installation)
- Dunnage: 2 crew, 50 m^2/day (100 m^2/day if several crews are working together on a larger-scale installation)
- Cofferdam Cells: 4 crew, 17 days per cofferdam cell set (1 major, 1 minor)
- Soil Nailing: 4 crew, 7 soil nails per day
- Pipe Piles: 5 crew, 2 piles per day
- Socketed Piles: 5 crew, 1 pile per day
- Fendering: 3 crew, 2 fenders per day
- Bollards: 3 crew, 1 bollard per day
- Pile Caps: 14 crew, 7 pile caps per day
- Steel Beam Reinforcement: 10 crew, 200 m/day
- Structural backfill: 3 crew, 600 m^3/day
- Concrete Decking: 10 crew, 500 m^2/day
- Steel Reinforcement for Concrete decking: 2 crew, 100 m^2/day
- Clear and Grub: 6 crew, 4000 m^2/day
- Riprap: 2 crew, 500 metric tons/day
- Dredging: 6 crew, 1200 m^3/day